1994

The role of eccentricity and size in the global precedence effect

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Amirkhiabani, Gholamali, The role of eccentricity and size in the global precedence effect, Doctor of Philosophy thesis, Department of Psychology, University of Wollongong, 1994. <https://ro.uow.edu.au/theses/1695>

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THE ROLE OF ECCENTRICITY AND SIZE IN THE GLOBAL PRECEDENCE EFFECT

A thesis submitted in fulfilment of the
requirements for the the award of the degree

Doctor of Philosophy

from

UNIVERSITY OF WOLLONGONG

by

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(Department of Psychology)

(1994)

SOURCES STATEMENT

I certify that the thesis entitled *The Role of Eccentricity and Size in the Global Precedence Effect*, and submitted for the degree of Doctor of Philosophy, is the result of my own research, except where otherwise acknowledged, and that this thesis (or any part of the same) has not been submitted for a higher degree to any other university or institution.

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Abstract

Studies on the global precedence effect have typically been concerned with the relative timing and interference of the global and local levels of a compound pattern. Navon (1977) purposed that global configurations are processed more quickly than are local components. Kinchla and Wolfe (1979) demonstrated that this global precedence was lost when the global stimuli exceeded 6-9 degrees of visual angle. Navon and Norman (1983) noted that Kinchla and Wolfe confounded size and eccentricity. They attempted to unconfound these two variables and concluded that global precedence was found with both large and small stimuli when eccentricity was not a confound.

It is argued that the controversy in the global precedence hypothesis has partially resulted from the fact that the concepts of the global and local and the attributed relationship between these two vary in different experiments and among workers. In the present study a new approach to global-local relationships was introduced. Global-local relationships were classified into four groups: Inclusion, placeholder, dimensional, and featural relationships. Any of these relationships may or may not be accompanied by a semantic relationship between the global and local levels. The Stroop-type interference of the global and local levels refers to some sort of conventional semantic relationship between the levels. Based on an extensive study of the literature it was suggested that the perception of the global and local levels of a compound pattern is dependent on the type of relationship between two levels. The presented study was limited to test the effect of size and eccentricity of the compound pattern on the processing of the global and local levels with inclusion and placeholder relationships.

Debate is still very active regarding the global precedence effect. The present study questioned the initial logic behind this hypothesis about the equal recognisability of the global and local levels, an axiom which has been accepted without being tested. This was investigated in a series of experiments by considering the effects of eccentricity and size and their possible interaction on the processing of the two structural levels, using compound patterns of placeholder and inclusion relationships. Furthermore, the possible

effect of size/eccentricity uncertainty on the temporal order of processing of the global and local levels and patterns of response times were examined across eccentricity. The results showed a global advantage regardless of attentional strategies or experimental presentation conditions when the eccentricity was controlled. The study of Stroop-type interference between the global and local levels indicated a discontinuity in global/local interference with variations in size and eccentricity. It seems that size and eccentricity are the main determinants of the global advantage effect. The pattern of results to any of the global and local levels suggested that the proportional enlargement of size and eccentricity of the stimulus resulted in a quadratic function of reaction times across eccentricity. This was explained by the decreasing exponential functioning of the size, and the increasing linear functioning of eccentricity when the other level was controlled.

ACKNOWLEDGMENTS

My sincerest appreciation goes to my supervisor, Professor William J. Lovegrove, for his continual academic assistance and advice, and good humoured encouragement. Without his invaluable comments and expert knowledge this work would never have been completed.

I acknowledge penetrating criticisms and positive suggestions of members of Applied Cognitive Studies Research Group of the University of Wollongong. Thanks are also due to the participants at the 20th and 21st Annual Experimental Psychology Conference where parts of the work carried out for this thesis were initially presented.

I owe sincere thanks to Dr. Steve Avons, Professor Ron King, and all the staff members of the Department of Psychology of the University of Wollongong for their positive criticisms, friendship, and support.

A special acknowledgment must be paid to my wife Minou, and my children Mani and Farangis for their patience and enthusiastic support. My sincere thanks are especially due to my late mother Najibeh and my father Jalil who taught me how to learn.

TABLE OF CONTENTS

	<u>PAGES</u>
Sources Statement	(ii)
Abstract	(iii)
Acknowledgments	(v)
Table of Contents	(vi)
List of Tables	(xii)
List of Figures	(xiv)
Chapter 1. Part-Whole Relationship	1
1.1 Whole and Part: An Epistemological Approach	2
1.2 Two Schools of Perceptual Thoughts	6
1.2.1 Structuralist Approach	6
1.2.2 Gestalt Approach	8
1.3 Perceptual Organisation	10
1.3.1 Object Properties	14
1.3.2 Levels of Description and Physical Properties of the Stimulus	16
1.3.3 Integral and Separable Dimensions	17
1.3.4 Parallel and Serial Processing of Whole and Parts	22
1.3.5 Top-Down Versus Bottom-Up Processing	24
1.3.6 Classifications of the Part-Whole Relationship	26
1.3.6.1 Emergent Properties	27
1.3.6.2 Kimchi and the Number and Size of Elements	31
1.3.6.3 Garner's Classification	33
1.3.6.4 Pomerantz and Type-N and Type-P Stimuli	34
1.3.6.5 Spatial and Hierarchical Local	35
1.3.6.6 Lasaga and Type-C and Type-D Stimuli	35
1.3.6.7 Semantic Relationship	37
1.4 The Concept of Whole: A Summary and Criticism	38

1.4.1 A New Classification	41
Chapter 2. Global/Local Processing	46
2.1 What is the Global/Local Precedence Effect?	46
2.2 Global/Local Precedence and Performance Measures	48
2.2.1 Stroop-Type Interference	52
2.2.2 Garner-Type Interference	56
2.2.3 Temporal Advantage and Global/Local Interference	59
2.2.4 Stationary and Queue Hypothesis	60
2.3 A Short History of the Controversy in the Literature	61
2.3.1 Global Advantage and Interference	61
2.3.2 Local Advantage and Interference	62
2.3.3 Reversal in Global/Local Advantage and Interference	64
2.4 Factors Affecting the Global/Local Advantage and Interference	67
2.4.1 Attention	67
2.4.2 Shape Goodness	69
2.4.3 Density/Sparsity	72
2.4.4 Number of Elements	74
2.4.5 Exposure Duration	76
2.4.6 Visual Fields and Hemisphericity	78
2.4.7 Eye Movements	80
2.4.8 Lateral Masking	82
2.4.9 Retinal Location	84
2.4.10 Eccentricity	85
2.4.11 Spatial Uncertainty	89
2.4.12 Size	91
2.4.13 Spatial Frequency	93
2.4.14 Similarity of the Global and Local Levels	96
2.4.15 Context Effect	98

2.4.16 Stimulus Type	98
2.5 Sources of Global/Local Advantage and Interference	99
2.6 Summary and Rationale	104
Chapter 3. Relative Size and the Global/Local Advantage and Interference Effects	110
Discriminability	111
Size	112
The Global Precedence Effect and Hemispheric Specialisation	114
3.1 Experiment 1	117
Method	118
Subjects	118
Apparatus and Stimuli	119
Design and Procedure	121
Results	122
General Discussion	127
Chapter 4. Source and Locus of Global Advantage	133
Controversy in the Literature	135
The Rationale and Purpose of the Present Study	136
An Outline of the Experiments of This Chapter	138
4.1 Experiment 2A	141
Method	142
Subjects	142
Apparatus and Stimuli	142
Design and Procedure	143
Results and Discussion	145
4.2 Experiment 2B	149
Method	151
Subjects	151
Apparatus and Stimuli	151

Design and Procedure	152
Results and Discussion	152
Comparison of the Results of Experiments 2A and 2B	155
4.3 Experiment 3A	157
Method	158
Results and Discussion	158
4.4 Experiment 3B	161
Method	161
Results and Discussion	162
Comparison of the Results of Experiments 3A and 3B	164
4.5 Experiment 4A	166
Method	167
Results and Discussion	168
4.6 Experiment 4B	171
Method	171
Results and Discussion	171
Comparison of the Results of Experiments 4A and 4B	173
Comparison of the Results of Experiments so Far	174
4.7 Experiment 5	176
Method	177
Results and Discussion	177
4.8 Experiment 6	184
Method	184
Results and Discussion	185
General Discussion	187
Chapter 5. Do the Global Advantage and	
Interference Effects Co-vary?	194
Global and Local Interference and Spatial Frequency Channels	194
Dissociation of the Global Advantage and Interference Effects	195

Task Requirement, Stimulus-Type, and Interference Effect	197
Goodness of the Shape and Global/Local Interference	198
Size of the Stimulus and the Interference Effect	200
Eccentricity	201
5.1 Experiment 7	202
Method	204
Subjects	204
Apparatus and Stimuli	204
Procedure	205
Results	206
Discussion	210
Global Advantage	210
Consistency Effect	211
Chapter 6. Types of the Global-Local Relationship and Outside-In Processing	215
Controversy in the Data and Conceptualisation	215
Outside-in Processing	218
The Present Study	222
6.1 Experiment 8	223
Method	223
Subjects	223
Apparatus and Stimuli	224
Design and Procedure	225
Results and Discussion	226
6.2 Experiment 9	228
Method	229
Results and Discussion	230
General Discussion	233
Chapter 7. Summary and Conclusions	236

References	244
APPENDICES	267
Appendix A	268
Appendix B	289
Appendix C	347
Appendix D	353

LIST OF TABLES

<u>Tables</u>	<u>Pages</u>
Table 1. Effect of Consistency on Reaction Times According to the Relative Size of the Global and Local Levels in Experiment 1.	268
Table 2. Effect of Consistency on Accuracy Rates According to the Relative Size of the Global and Local Levels in Experiment 1.	268
Table 3. Analysis of Variance on RTs in Experiment 1.	269
Table 4. Analysis of Variance on Accuracy Rates in Experiment 1.	279
Table 5. Mean RTs (msec) and Accuracy Rates (%) in Experiment 2A.	289
Table 6. Mean RTs (msec) and Accuracy Rates (%) in Experiment 2B.	290
Table 7. Mean RTs (msec) and Accuracy Rates (%) in Experiment 3A.	291
Table 8. Mean RTs (msec) and Accuracy Rates (%) in Experiment 3B.	292
Table 9. Mean RTs (msec) and Accuracy Rates (%) in Experiment 4A.	293
Table 10. Mean RTs (msec) and Accuracy (%) Rates in Experiment 4B.	294
Table 11. Mean RTs (msec) and Accuracy Rates (%) in Experiment 5.	295
Table 12. Mean RTs (msec) and Accuracy Rates (%) in Experiment 6.	296
Table 13. Analysis of Variance on RTs in Experiment 2A.	297
Table 14. Analysis of Variance on Accuracy Rates in Experiment 2A.	301
Table 15. Analysis of Variance on RTs in Experiment 2B.	304
Table 16. Analysis of Variance on Accuracy Rates in Experiment 2B.	308
Table 17. Analysis of Variance on RTs in Experiment 3A.	311
Table 18. Analysis of Variance on Accuracy Rates in Experiment 3A.	315
Table 19. Analysis of Variance on RTs in Experiment 3B.	318
Table 20. Analysis of Variance on Accuracy Rates in Experiment 3B.	322
Table 21. Analysis of Variance on RTs in Experiment 4A.	325
Table 22. Analysis of Variance on Accuracy Rates in Experiment 4A.	329
Table 23. Analysis of Variance on RTs in Experiment 4B.	332

Table 24. Analysis of Variance on Accuracy Rates in Experiment 4B.	336
Table 25. Analysis of Variance on RTs in Experiment 5.	339
Table 26. Analysis of Variance on Accuracy Rates in Experiment 5.	340
Table 27. Analysis of Variance on RTs in Experiment 6.	341
Table 28. Analysis of Variance on Accuracy Rates in Experiment 6.	344
Table 29. Mean RTs (msec) and Accuracies Rates (%) to Consistent and Inconsistent Stimuli in Experiment 7.	347
Table 30. Analysis of Variance on RTs in Experiment 7.	348
Table 31. Analysis of Variance on Accuracy Rates in Experiment 7.	351
Table 32. Mean RTs (msec) and Accuracy Rates (%) in Experiment 8.	353
Table 33. Mean RTs (msec) and Accuracy Rates (%) in Experiment 9.	353
Table 34. Analysis of Variance on RTs in Experiment 8.	354
Table 35. Analysis of Variance on Accuracy Rates in Experiment 8.	355
Table 36. Analysis of Variance on RTs in Experiment 9.	356
Table 37. Analysis of Variance on Accuracy Rates in Experiment 9.	358

List of Figures

<u>Figures</u>	<u>Pages</u>
Figure 1: A sample Type-C (a) and Type-D (b) stimuli (Lasaga, 1989).	36
Figure 2: Stimuli used in Kinchla's (1977) experiment.	49
Figure 3: The stimulus set reported in Lasaga's (1989) study.	52
Figure 4: Stimuli used in Wandmacher and Arend's (1985) study.	55
Figure 5: The logical structure of the stimulus set used by Pomerantz (1983).	56
Figure 6: The six stimulus sets used in Pomerantz and Sager's study (Pomerantz & Sager, 1975).	63
Figure 7: The four sets of compound patterns used in Kimchi and Palmer's (1985) study.	66
Figure 8: A sample of stimuli used in Experiment 1.	119
Figure 9: Mean RTs as a function of target level and relative size in Experiment 1.	123
Figure 10: Mean RTs as a function of target level, relative size, and consistency in Experiment 1.	124
Figure 11: Mean reaction times as a function of target level and visual field in Experiment 1.	125
Figure 12: The set of stimuli used in Experiments 2A, 3A, and 4A.	143
Figure 13: Mean RTs as a function of target level and eccentricity in Experiment 2A.	146
Figure 14: Mean RTs as a function of target level and eccentricity in Experiment 2B.	153
Figure 15: The comparison of patterns of responses in Experiments 2A and 2B.	156
Figure 16: Mean RTs as a function of target level and eccentricity in Experiment 3A.	159
Figure 17: Mean RTs as a function of target level and eccentricity in Experiment 3B.	163

Figure 18: The comparison of patterns of responses in Experiments 3A and 3B.	165
Figure 19: Mean RTs as a function of target level and eccentricity in Experiment 4A.	169
Figure 20: Mean RTs as a function of target level and eccentricity in Experiment 4B.	172
Figure 21: The comparison of patterns of responses in Experiments 4A and 4B.	174
Figure 22: Mean RTs as a function of eccentricity in Experiment 5 (four constant sizes).	178
Figure 23: Mean accuracies as a function of eccentricity in Experiment 5 (four constant sizes).	179
Figure 24: Mean RTs as a function of size in Experiment 6 (two constant eccentricities).	185
Figure 25: The set of stimuli used in Experiment 7.	204
Figure 26: Mean RTs as a function of target level and eccentricity in Experiment 7.	207
Figure 27: Mean RTs as a function of target level, eccentricity, and consistency in Experiment 7.	208
Figure 28: The set of stimuli used in Earhard and Walker (1985) and Earhard's (1990) studies.	219
Figure 29: The set of stimuli used in Experiment 8.	224
Figure 30: Mean reaction times as a function of target level and visual angle in Experiment 8.	227
Figure 31: The set of stimuli used in Experiment 9.	229
Figure 32: Mean RTs as a function of target level, visual angle, and consistency in Experiment 9.	231

Chapter 1

Part-Whole Relationship

The relationship between the whole and part is a 'stock' question both in the history of human knowledge and psychology of perception (Woodworth & Schlosberg, 1954). The main thrust of this thesis is to examine if the earliest perceptual stages reflect our subjective experience of wholistic objects which are later analysed into distinct properties, or if initial properties and events are synthesised to form wholistic perceptions. There is evidence for and against both approaches. Some workers (e.g., Treisman, 1986) have suggested that percepts are the results of synthesising component properties. Others (e.g., Navon, 1977) have argued that whole is registered first followed by its progressive analysis into parts.

The terms wholistic and global precedence are usually used interchangeably to refer to the hypothesis that recognition, discrimination, or classification of objects initiate from first processing wholistic (i.e., global) properties rather than the processing of the component parts (Kimchi, 1992; Navon, 1977, 1981a). The global precedence hypothesis is a theoretical account of any type of empirical evidence regarding the faster or earlier processing of the global structure (i.e., wholistic property) or its distinctiveness during the processing of a stimulus.

The global precedence hypothesis has been developed in a frame-work in which a visual structure was viewed as a hierarchical network of sub-structures related to each other by the place they occupy within the hierarchy (Kimchi, 1992; Kimchi & Goldsmith, 1992). For example, a face as a structure is composed of eyes, nose, ears, etc. Each of these components is constituted of lower level structures (e.g., eyes which consist of lashes, pupils, eye lids, etc.). It has been assumed that the global and local levels are equally complex, recognisable, codable, and one cannot be predicted from the identity of the other (Kimchi, 1992). When the global and local levels are equated according to these parameters it seems possible to compare them by a performance measure such as relative

reaction time and/or asymmetric interference (Kimchi, 1992; Kimchi & Goldsmith, 1992). All these appear to be well-developed assumptions, except for two points. First, it is not clear exactly if the levels of a hierarchical structure correspond to the levels of perceptual functioning of human perception. Second, there is not much agreement on the operational definitions of the whole and part. In the following sections these issues will be discussed in more detail, but first I will show that part-whole relationship has roots in the long history of epistemology.

1.1 Whole and Part: An Epistemological Approach

Argument on the part-whole relationship in psychology of perception can be traced back to philosophy. The question of whether perception is wholistic or analytic has engaged the interest of philosophers for centuries. It is not enough to consider the problem of the global precedence effect in the isolated context of one's own discipline as many scholars do. Therefore, it seems reasonable to trace back the existing discussions on part-whole relationships in philosophy. The problem of perceivability of things and phenomena and knowledge about them are the main subjects in epistemology. Epistemology loosely defined is a branch of philosophy that investigates the nature, origin, and methods of human knowledge (Ginsberg, 1977; Krecz, 1986; Tiles, 1993; Willard, 1982). Human knowledge is in the form of concepts. If these concepts correspond to something that is found in reality, man's knowledge has a foundation in fact. However if they do not correspond to things in reality, they are nothing except for imaginations (Moore, 1953).

Granted that we can be perceptually deceived in many ways, a major question in epistemology is whether our knowledge is certain. That is, can we acquire a realistic and reliable knowledge of what we perceive. There may be at least two answers to this question: positive and negative. Those who believe that we cannot know whether the concepts do correspond to anything in reality (sceptics) argue that there are no means to acquire such knowledge and no criteria to test its reality. However, those who believe in a

correspondence between concepts and things in reality, have to indicate some criteria to examine this correspondence and a tool to acquire true knowledge about the world.

In the history of philosophy, there are, essentially, three schools of thought in epistemology: Scepticism, rationalism, and empiricism. Sceptics are those who suggest that we can never know if our concepts correspond to anything real. Rationalists are inclined to emphasise the importance of man's mental ability, abstraction, reasoning, deduction, and a top-down flow of knowledge in the process of consciousness. The empiricists have suggested that knowledge results from bottom-up, analytic processing, i.e., from the processing of the perceived stimulus. In fact, empiricists argue that there is nothing beyond the stimuli. Rejections of all metaphysics and a strong respect of science and scientific method are the characteristic of historical empiricism. In contrast to empiricists who emphasise the importance of environmental factors, and data driven cognition, rationalists have suggested that cognition is a conceptually driven and top-down process.

There has been a strong emphasis in philosophy on the subjective tendency of human mind to perceive knowledge in terms of wholistic properties (e.g., Engels, 1940; Hegel, 1969; Husserl, 1900/1970). Hegel (1969) proposed the concept of the unity of whole and parts. He distinguished between mechanical and organic entities. Giving the example of an organism, Hegel suggested that the limbs and organs of an organic body are not merely parts of it. It is only in their unity that they are what they are, and they are unquestionably affected by that unity, as they also in turn effect it. In contrast, the combination of the elements of granite has no effect on the elements (Hegel, 1969). However the external and mechanical relation of whole and parts is not sufficient if we want to study organic life in its truth. In Hegel's philosophy, the idea that the whole is something more than or at least different from parts, was expressed by the triad of thesis, antithesis, and synthesis. This dialectical approach had already been proposed by Plato and Socrates using different language. Discussing the forms of fire, heat, snow, and cold, Plato (1972) had a Socrates say when he proposed that under the influence of heat

they will not remain snow and heat, but at the advance of heat, the snow will either retire or perish; and the fire too at the advance of the cold will either retire or perish.

The concept of "idea" in Plato's philosophy is an indication of the dominance of the concept of whole in his system. Although man can perceive only a continual play of shadows of the reality and not the reality itself according to Plato's parable, knowledge can be acquired by and through human reasoning and mind. The concretes we perceive are merely the imperfect reflection of abstracts which exist as real entities. The emphasis on the dominance of the whole in part-whole relationships has continued its life among recent philosophical works. Moore (1953) proposed that the value of the whole differs in degree from the sum of the values of its parts (Pal, 1991). According to Bahm (1972) from a philosophical view, wholes and parts interdepend on each other. There are at least three kinds of wholes: aggregate, mechanical, and organic. The latter sort of whole is complicated, because of the mutual dependence of the whole and part. Therefore, a change in one involves a change in the other.

In contrast, Aristotle explored his notion of infinite divisibility of a whole. By definition an infinite set has the same cardinality (Power). That is the whole is not larger or more than the sum of its elements (Strauss, 1987). Meanwhile, the philosophical thoughts after the Renaissance were profoundly impressed by the analytic approach inherited with empiricism, with less emphasis on the whole in contrast to the parts. For example, according to Spencer (1915) parts are increasingly complex. However, a whole which can be a principle and must not be taken as organic, composite or additive, is simple. That means wholes are simple and parts are complex. John Locke established an epistemological approach based on the idea that intellect is the reflection of the outside world via the senses (Woolhouse, 1971). He distinguished between the physical objects, the simple ideas or senses that are raised from the physical world, and the complex ideas that come out of the experience (Shaw & Turvey, 1981). In fact, Locke grouped objects into real objects whose perception was indirect and mental objects whose perception was directly an experience. However, as an empiricist he believed that perception is analytic rather than wholistic.

Husserl's view (1900/1970, p. 437) of parts and wholes is very close to some contemporary concepts in visual perception. He defined (p. 437) a part as anything "that can be distinguished in an object." Husserl differentiated between dependent and independent parts. Independent parts are those that can be distinguished regardless of the whole of which they are part. Leaves are independent parts of a tree. We may have a leaf apart from a tree. However, dependent parts are inseparable from their whole. For example, the colour of a leaf is inseparable from the leaf. We cannot have greenness without something which is green. This classification has similarities with the concepts of integral, separable, and separated properties proposed by Garner (1974, 1983) and Pomerantz (1983) to be discussed later. In addition, Husserl differentiated between two types of wholes: Wholes which are made from independent parts and have a structure like a collection or an aggregate. Wholes which are given as a "perceptual and continuous whole" and their parts are "contained in them and only subsequently separated out" (Husserl, 1900/1970, p. 480).

The idea of wholistic perception seems to be in contrast to the essence of scientific behaviour which is analytic (Garner, 1981; Sacksteder, 1985). It seems that the process of understanding a phenomenon is by analysing it and taking it into parts. Therefore, it has always been a problem how perception can be wholistic while to be able to understand it as a scientist we try to analyse it in parts. To answer this paradox Garner (1981) suggested a dual epistemology. A primary epistemology which is appropriate to the ordinary perception and a scientific epistemology or metascience which suits the scientific method. Garner argued that most of perception involves a complete lack of analysis by perceiving individuals. Stimulus properties such as good shape, rhythm, and motion are perceived as wholistic properties (Garner, 1981).

In summary, what has been proposed in the global precedence hypothesis has its routes in the history of human knowledge. In fact, this hypothesis is partly an experimental endeavour to discover the nature, origin, and methods of human knowledge; an attempt to clarify how perceptual organisation integrates temporally and spatially segregated percepts. It is impossible to arrive at a common conclusion at this stage and at

this level of explanation. Perhaps, recent physiological studies on the functions of left and right hemispheres have provided some objective bases for some sort of compromise between the two views (e.g., Robertson, Lamb, Zaidel, 1993). It is suggested that the usually dominant left hemisphere is involved with language functioning, analytic thinking and the breakdown of sequential forms. On the other hand, the non-dominant right hemisphere controls wholistic perception (D' Aquili, 1990). What was concluded from these results was the presence of two distinct types of consciousness within a unified head, a unitary whole. In fact, wholistic/analytic dialectic seems to be the disposition of human perception. The endeavour of the present research is to provide some experimental findings that contribute to the long lasting philosophical and psychological debate on the relationship between physical, subjective, and functional properties of stimuli in general and the part-whole relationship in particular. Philosophical debates on part-whole relationship have been extended to theories of perception.

1.2. Two Schools of Perceptual Thoughts

The major discussion on part-whole relationship can be traced back to the historical controversy between two major schools in the psychology of perception: Gestalt and structuralism. In continuation of this introductory chapter, aspects of Gestalt and structuralism that are directly relevant to the issue of part-whole relationship will be discussed. The study of structuralism and Gestalt psychology is significant because of their emphasis on perceptual structure and specifically on the part-whole relationship.

1.2.1 Structuralist Approach

Titchener (1909) and Wundt (1874), who were impressed by English empiricism with its emphasis on atomism and associative mechanisms as the dominant school of thought, and the impressionistic approach in art at the turn of the twentieth century, argued that the centre of interest for experimental psychology does not lie in the field of thought. That is why Titchener (1909) called himself an experimentalist and distinguished himself from traditional sensationalists and associationists. Traditional sensationalism

refers to a theory according to which the knowledge is based on sensation (Titchener, 1909). Based on the physiological findings of the nineteenth century sensationalists argued that physiological conditions effect consciousness. In other words, nervous sets and tendencies regulate and direct consciousness. That is all cognition can be traced back to elementary sensations. Although sensationalism before Titchener had some aspects in common with associationism, Titchener believed that the sensationalism in his view of experimental psychology should not be confused with the associationism and traditional sensationalism. He aimed to describe consciousness not as what it means but as it is. In this sense, 'experimental psychology'- which is what Titchener regarded himself to belong to- was different from associationistic and atomistic approaches.

According to structuralism which was rooted in the physiology of nineteenth century, a sensory whole is made up from a conglomerate of primary sensations and it corresponds to the physical objects by associative learning (Kimchi & Goldsmith, 1992). Therefore, Titchener dealt with experience and not with meanings; and the elements of his approach were processes and not substances. In fact Titchener's psychology was not wedded to sensation. He simply preferred to work with as few tools as possible, and sensation and affection seemed to give him all that he needed for the work of analysis. What is important from Titchener in the context of the present research is his analytic approach towards the explanation of cognitive activities. This approach is in contrast to the primacy of the wholistic properties in Gestalt psychology.

It is usually said that Structuralists denied the existence of perceptual organisation (e.g., Kimchi, 1992; Pomerantz & Kubovy, 1986; Treisman, 1986). As was mentioned previously, this does not seem to be correct, at least concerning the Titchener's view. He was aware of the functioning of the other cognitive dimensions. In fact, he was distinct not because of his denial of perceptual processes but because of his analytic approach to the main problems of psychology. According to this approach identification, detection, recognition, and classification of the perceptual objects are through the combination of the percepts of their elements. The analytic approach of Structuralists has been rephrased in many of current models of perception (Kimchi, 1992). Generally Structuralists emphasise

the crucial importance of parts on the perception of a stimulus. They viewed sensory organs as innate systems which pass on the sensation to sensory elements of the brain. They put much weight on learning which form the percepts gradually as the result of association among memory images.

1.2.2 Gestalt Approach

The global precedence hypothesis has brought the Gestalt psychology to the centre of attention again (See, Kimchi, 1992; Kubovy & Pomerantz, 1981). Gestalt psychology is based on two major thrusts: the first has been conveyed by the commonly cited view that the whole is greater than the sum of its parts, and the other is the assumption that objects and events are the primary and basic units of our perception (Treisman, 1986). Anyone who believes in the existence of perceptual Gestalts should accept that a whole is not the sum of its parts. There are two general tendencies in the Gestaltist interpretation of the relationship of whole and parts. Some workers such as Kubovy (1981) believed that whole is equal to its parts plus the relationships among them. Others (e.g., Treisman, 1986) suggested that sum of parts is simply different from a whole, and not necessarily less than it.

The most serious argument between Gestaltists and Structuralists was that the latter suggested that sensations are superimposed upon each other in a linear perceptual system, while Gestaltists suggested a nonlinear interaction of perception within the perceptual system (Pomerantz & Kubovy, 1986). Gestaltists suggested that there are similar structures both in the brain and objects. Learning occurs when these two structures coincide with each other (Koffka, 1935/1963; Kohler, 1971). In fact, learning is a consequence of and not the determinant of perceptual structure (Pomerantz & Kubovy, 1986). The structure of stimuli and the brain are in a manner that the wholistic properties of the stimuli such as the configuration, symmetry, and closure are perceived independently of the components of the stimuli and they precede the processing of the component parts. Generally speaking analysis of the percept into its parts is not a normal routine of the perceptual system.

Gestalt psychologists have argued that perceptual coherence and dominance of wholes originated from basic organising principles (Kohler, 1947). They provided a large number of principles which govern perceptual organisation, such as laws of area, proximity, similarity, closure, good continuation, convexity, symmetry, enclosure, colour and contrast, and common fate (Pomerantz & Kubovy, 1986; Sekuler & Blake, 1985). The organisational principle of 'pragnanz' or minimum principle is the heart of Gestalt view of perception (Pomerantz & Kubovy, 1986). According to this principle the organisation of stimuli is such that it simplifies the perception of their global aspects. Perhaps, the main premise of Gestalt approach is that perception is organised globally to be able to simplify the representation of wholistic stimulus configurations.

It appears that pragnanz serves as the cornerstone of the Gestalt approach (Pomerantz & Kubovy, 1981). In fact, the purpose of all other principles of grouping and figure-ground segregation is to achieve the simplest, best, and most stable organisation of the object. Although other principles of Gestalt psychology such as similarity or proximity can operate locally, pragnanz emphasises the global quality of stimuli. To Gestalt psychologists, perceivers perceive objects or scenes that most simply or economically fit the sensory pattern (Hochberg, 1981). However, the main paradox of the Gestaltist approach is to specify what simplicity or economy means. In fact, the most serious difficulty of the Gestalt view is that it is not clearly defined what "simplest" or "best" are. Therefore, some workers have perceived some ambiguities with this approach. For example, Pomerantz and Kubovy (1986) suggested that this principle is inadequate to explain the Gestalt phenomena.

Generally Gestalt psychology suggests that the whole is not only different from the sum of its parts, but also it is perceived prior to the parts. Gestalt psychologists argued against atomism and the role of learning in perception, and emphasised the role of extended units and perceptual organisation. In contrast to Structuralists, Gestaltists proposed that the perception of properties of an object is not the product of the addition of sensory elements, but is a direct result of the processing of the electrical field of the brain in response to wholistic pattern of the visual object (Kimchi & Goldsmith, 1992).

Gestaltists employed the method of phenomenology. Their main concern was the relationship between the whole and its components. However, the Gestalt view that certain components lose their identity when embedded within a whole, does not preclude the possibility that these components have been used in the processing of the perceived whole (Lasaga, 1989). Although Gestalt psychologists provided valuable data on the salience of subjective wholes, they were not able to offer strong evidences in support of the primacy of wholistic analysis in perceptual codings (Treisman, 1986). However, we have now far better evidence than Gestalt psychologists that perception is organised (Pomerantz, 1986). It seems that despite the fuzziness of Gestallean concepts they remain heuristic and a guide to research. Part-whole relationship as the basic tenet of the Gestalt Psychology needs to be studied in the broader context of perceptual organisation.

1.3 Perceptual Organisation

How we manage to make typically accurate and unambiguous percepts from the information detected by our sensory systems is central to the concept of perceptual organisation (Beck, 1982; Broadbent, 1958; Woodhouse & Barlow, 1982). Perceptual organisation refers to "the process by which particular relationships among potentially separate stimulus elements (including parts, features, and dimensions) are perceived, (i.e., selected from alternative relationships) and in turn guide the interpretation of those elements" (Pomerantz & Kubovy, 1986, pp. 36-6). The underlying assumption of most of the studies on perception is that perception is an organised process. Otherwise, if the presence of any organisation was rejected, or if the perception had the same structure as the environment, there would be no place for discovering principles of perceptual organisation (Pomerantz & Kubovy, 1986). In this chapter I plan to consider the problem of part-whole relationship.

The question of how we process sensory information is the basic question in the study of perception. In fact, identical responses which are made by different people or by an individual on different occasions reject the possibility of chaos in perceptual processing. Meanwhile, the variation in responses to a specific stimulus indicates that our

perception does not operate as a sheer reflection of the environment. Therefore, it seems reasonable to assume the presence of some general trends or major functioning routes or strategies in perceptual processing. The idea underlying studies in human perception is the belief that perception operates within an organisation. Pomerantz and Kubovy (1986) nominated the process by which the relationships among different elements (such as parts, features, and dimensions) of a stimulus are perceived, as perceptual organisation; and they grouped the phenomena of perceptual organisation into four major categories: the problem of perceptual coupling, the problem of grouping and part-whole relationships, the problem of figure-ground organisation, and the problem of multi stability.

How do we manage to interpret the information that has been received by our sensory receptors? It seems that our perceptual system not only detects information from our environment but also normally organises information in an unambiguous manner. In any perceptual event the decision made by our perceptual system depends on the information received from the sensory system, from the surrounding context of the stimuli, from past memory about similar events, and from the rules "wired" into the nervous system, or from any combination of these (Pomerantz & Kubovy, 1986). Perception of a pattern seems to be a multidimensional process. It is probably composed of an early perceptual and even sensation processes, processes of an attentional nature, and even some processes that may involve decisions and response selection (Kimchi, 1990). Findings regarding the similarity of perceptual organisation of adults and young children (e.g., Kimchi, 1990) suggest that sensory and early perceptual factors play an important role in the processing of such patterns.

It has been suggested that perception of an object goes through stages. One of the most elegant interpretations of visual perception was proposed by Treisman (1986). Treisman suggested an early, parallel, preattentive registration of isolated properties and parts, a level of grouping and synthesising into structured relationships to constitute representations of as yet unlabelled objects, and a level of identification, recognition, or classification of the objects and their settings by means of prior knowledge. According to this worker, a set of specialised analysers initially analyses various properties. Then

different components are integrated to form a structured representation that mediates conscious experience. To ensure the correct integration of separately but parallel analysed information from the first level of processing, 'focused attention' seems to be required. The second level is assumed to interface between the other two levels. It can be accessed from either direction. An unknown object may be perceived from the sensory input, whereas known objects are imagined and the perception of their parts and properties may be primed. Both directions will be active and interact with the others in forming final percepts. The global units are constituted by early groupings according to their dependence on the real-world entities (Rosch & Lloyd, 1978). At this level, features are segregated from ground, and the detected properties may provide information about surface, slants, and identity of the objects. Despite the generally accepted view of a single, global, preattentive organisation, Treisman proposed that the synthesis may not be achieved until the construction of three-dimensional representations. This view is consistent with recent physiological evidence (e.g., Frisby, 1980; Mollon, 1979; Robson, 1980) on multiple projections of visual properties in different specialised cortical areas. Therefore, the question of whether perception is analytic or integral should be separately answered regarding the early preattentive and unconscious level, and subjective experience of the perceived stimulus (Kinchla, 1992; Treisman, 1986). Although we may subjectively have an initially wholistic result of our perceptual experiences, they are not necessarily the same as the earliest coded neural representations. Even at the level of subjective experience of the perceived, the answer to this question seems to be closely related to both physical properties of the stimulus and past memory of the subject.

It has been suggested (e.g., Treisman, 1986) that preattentive processing results in distinct and separate representations for separate properties of the stimulus. However, if it is true, how are these distinct properties combined to give a unified percept? Treisman (1986) proposed that the information to conjoin the separate sets of properties and parts may be provided by emergent features. The perception and identification of percepts are different from a list of their properties. With an expected object a single feature or set of features are sufficient for recognition. A hat in the right context may result in the

identification of an expected friend. It appears that normal vision stands somewhere in between of the extremes of recognition based on previous knowledge and identification based solely on sensory data. Since a simple list of disjunctive features may be common between some possible objects, the relations between features have to be verified (Treisman, 1986). These relations may be exemplified as spatial relations, such as below, between; comparative relations, as brighter or wider; or higher order properties such as homogeneous or symmetrical. In fact, according to Treisman there is much previous knowledge regarding rules of events and descriptions of objects which disambiguates the input data. According to this interpretation perception under normal conditions may consist of fitting the most expected global object or event to the sampled sensory components.

Therefore, the main problems facing us today are similar to those faced by Gestalt psychologists during the first half of this century (Pomerantz & Kubovy, 1981). First, the problem of correspondence between stimuli, brain, and perception (isomorphism) has been of major concern to both Gestalt psychologists and to us. Second, the permanent contribution of Gestalt psychology is the wealth of information they provided to show that percepts are organised in the simplest possible way (*pragnanz*). Finding general principles or heuristics of perceptual functioning is still one of the endeavours of the psychology of perception. Third is the problem of part-whole relationships. It has been frequently suggested that there are two different perceptual levels corresponding directly to the whole and parts (e.g., Kimchi, 1992; Kimchi & Palmer, 1982; Navon, 1977). Phenomenological and experimental evidence has been also provided to show that wholes are different from the sum of their parts (e.g., Pomerantz & Kubovy, 1981).

The perception of any simple stimulus, such as an array of dots alternating between two organisations, may suggest that organisation is something different from the parts. However, the main issue is to clarify what property of a whole is different from what properties of the parts. For example, symmetry as a wholistic property is different from sum of the identities of two lines, but it is not different from sum of their spatial locations. Therefore, when we say a whole is different from sum of its parts, it is important to

clarify what property of a whole is different from what property of parts. Otherwise this expression is nothing more than redundancy, and by such an expiration nothing will be added to the definitions of whole and part except for ambiguity. Meanwhile, how whole and parts are treated in perceptual processing is an important issue in the study of perception. The question has recently gained new significance, following the proposal that the perceptual system employs mechanisms for indirect detection of complex stimuli. One of the major issues surrounding part-whole relationships is the precedence of either the whole or part. Obviously both wholes and parts can be perceived independently. However, we need to know if the perception of parts needs to mediate the perception of a whole. This review does not study all aspects of perceptual organisation. The main thrust of the present study is to examine part and whole as properties of the visual object.

1.3.1 Object Properties

Unfortunately there is much ambiguity about the concepts and stimuli used in the part-whole relationships. Different stimuli have been used without providing a clear definition of their properties. Because of this confound it seems reasonable to provide definitions of stimulus properties. The concept of property is used as a general term in a relatively undifferentiated way throughout the present research. One of the earliest classifications of stimulus properties belongs to Garner (1970, 1974, 1978a). According to Garner there are two major groups of stimulus properties: component properties and wholistic properties. Garner called component properties 'attributes' and grouped them into two major subclasses: dimensions and features. Attributes are component properties that help to define stimuli but are not synonymous to them.

According to Garner dimension is an attribute that when it exists, it is at some positive and exclusive level (or value). For example, brightness as a dimension should exist at a particular level, and there cannot be two or more hues simultaneously. Zero is a positive level for a dimension. In contrast, a feature is a property of stimulus that either exists or does not exist. However when it exists, it has only one level. It is an element of the stimulus that can be taken away without affecting the rest of it. For example, the

horizontal line in the middle of the letter H is a feature of it, and it can be removed without affecting the other parts of it (of course, its removal affects the global configuration). In contrast, if the dimension of brightness or colour is removed from a stimulus it will affect all the components. With feature zero we mean that an attribute does not exist, but zero is a positive value for a dimension. Quoting an example from Garner may make the concepts of feature and dimension clearer. If a set of stimuli are generated by a vertical line as a handle to attach features, which are horizontal lines at the top, middle, and bottom of the handle, then we have three features locating at three locations of the vertical handle. It is possible to generate eight possible stimuli by the presence or absence of any of these features, some of which are identifiable as upper-case letters, F, E, L, and C. However, if we generate only one horizontal line in one of the bottom, middle, and top locations of the vertical handle, in this case we will have three stimuli and the horizontal line will have a dimensional attribute.

Treisman (1986) extended Garner's (1978) view of object properties of the compound pattern. According to Treisman, at least three general modes of analysis are distinguishable in the visual perception: dimensions, features, and parts. Each of these modes of analysis, according to this worker, can be applied in any of the following domains of description: physical, functional, and subjective. The general terms "property" or "attribute" may be used to refer to any of these aspects (Treisman, 1986). According to Treisman a dimension can be defined as a set of varying values of which only one property characterises any non-composite stimulus to which a dimension applies, such as brightness. Some dimensions may depend on combinations of simpler dimensions. Features refer to a subjective classification among objects by a few discrete categories such as, large or small, old or young, green or blue. According to Treisman, if there is a little overlap in the perceived properties of two stimuli, perception will tend to be categorical, and it is better to speak of features than dimensions. Classification and identification tasks are related to discrete features, whereas in discrimination tasks continuous dimensions are involved. Generally the human perceptual system is specialised to classify physical stimuli into discrete regions within which dimension is

poor or impossible. Division into parts differs from dimensional and featural analysis in which parts are not necessarily characteristics of a stimulus (Treisman, 1986). Labels for parts are confused with labels for dimensional values or features. Parts of an object may be decomposed in further parts. Sometimes the identify of parts are important with regard to the identity of an object. However, in some other condition only the arrangement and not the identity of parts forms an object. Physical properties of the stimulus can be viewed from different perspectives. In the following section this issue will be discussed in more detail.

1.3.2 Levels of Description and Physical Properties of the Stimulus

There are at least three levels or domains of description of a visual stimulus (Treisman, 1986): the physical domain which describes the properties of stimuli reaching the receptors, the conscious domain which concentrates on the subjective experience of the perceived stimulus, and the functional domain which studies the nature of perceptual codes used for perceptual processing. The study of the latter domain forms what is called perceptual organisation. The relationship between these dimensions seems to be complicated. Subjective reports are not necessarily correct interpretations of functional processing. Meanwhile, the coded representation of the nervous system does not need to directly parallel the subjective interpretation of objects and events. One of the difficult problems in the psychology of perception is to understand the nature of transformation of information from physical stimuli into the visual representation of real objects and events. It seems that there is not a simple correspondence between the stimulus and perceptual organisation. Therefore, perceptual objects may be different from physical stimuli in the specificity of information they carry.

From a subjective view an object can be described as possessing some possible properties. For example, a canary is described as a flying, yellow, singing bird. The problem is to discover the functional units of processing which result in perceptual identification. Are the functional units of dimensional values, features, localised parts,

and the whole properties the same? The functional dimension is a hypothetical construct therefore, we only speculate on its attributes. Even when experimental tests verify a level of functional processing, it may not be clear which mode (dimension, feature, and parts) and what level of a mode is processed. Therefore, the distinction between the domains of subjective experience and functional codes is important (Treisman, 1986). Meanwhile, as Treisman suggested the perceptual dimension does not seem to be a function of a single neural channel. However, the fact of specialisation in analytical arrangement of cortical areas supports the idea of dimensional decomposition in the neural codes of perception (e.g., Regan, Silver, & Murray, 1977; Richards, 1977).

Physiological studies on selective lesion damage with brain damaged individuals and selective adaptation, masking and interference are used to speculate on the nature of psychological coding of perceptual stimuli (See Treisman, 1986 for a review). If damage to a particular cortical area causes an impairment along a dimension, without any other impact, it would be evidence for independent processing of that dimension. However, double dissociations may be interpreted as indicating that damage to one area causes an impairment to another area. In this condition the wholistic possibility of perception will be ruled out (Treisman, 1986).

1.3.3 Integral and Separable Dimensions

Garner and his associates (e.g., Garner, 1974; Garner & Felefoldy, 1970) suggested an elegant classification of the structure of a percept. They classified visual dimensions as "integral" and "separable" and suggested that the properties of the former type, such as the value and chroma of a colour chip, are not selectively attendable. That is, variations in the relevant property of a dimension produce interferences on the processing of the other. Integral dimensions are perceived unitarily and a change in any of these dimensions produces a qualitatively different stimulus (Garner, 1974), whereas with the separable dimensions, such as colour and form of a stimulus, 'selective attention' to one dimension is possible without being interfered with by the other. Stimuli varying along separable dimensions, such as size and colour, are perceived as being separable.

It is suggested that integrality and separability of pairs differing in both size and form or in both size and brightness should be judged according to the sum of the unidimensional dissimilarities (Attneave, 1950). This was explained by a city-block metric in which dimensions are registered independently (Melara, Marks, & Lesko, 1992). On the other hand, integral dimensions such as brightness and saturation combine according to Euclidean metric (Treisman, 1986). Treisman also proposed that the integral and separable properties are explained by Euclidean and city-block metrics, respectively.

In fact, according to Garner (1974) two dimensions of a visual object are integral if the existence of one requires the existence of the other. In contrast when there is no constraint for the existence of two dimensions, they are separable. However, it seems that integrity and separability operate within a continuum (Shepp, 1989b; Shepp, Barrett, & Kolbet, 1987). Shepp (1989b) made a distinction between separable and separate dimensions and proposed that separate dimensions are perceived independently regardless of the task demand or age of the observer, whereas the perception of the separable dimensions is highly dependent on the task demand and subject's age.

According to Shepp (1989b) there are meaningful distinctions between integral, separable, and separate stimuli. He defined integral stimuli as those which are perceived as unitary wholes and cannot be analysed into their constituents. Separable stimuli are easily analysable into features, whereas separate stimuli are generated by combining spatially separated dimensions. According to this worker, patterns of responses to integral and separable tasks are similar in speeded tasks. However, in unspeeded tasks separable and separate stimuli provided different patterns of responses. Therefore, he suggested that separable stimuli may be perceived either holistically or analytically. Shepp, Barrett, and Kolbet (1987) studied the operation of wholistic and featural properties in 'selective and divided' attention conditions with spatially separated and integral stimuli. The results of that study indicated that a separable figure was perceived initially as a whole.

Based on the existing literature it may be suggested that most dimensional properties are separable (Treisman, 1986). A few seem to be integral, such as hue, lightness, and saturation, although colour is separable from other dimensions.

Meanwhile, spatial coordinates such as horizontal and vertical position and distance (heights and widths) appear not to be psychologically coded independently. For some other dimensions such as size and lightness, and dimensions of components there is not yet any clear-cut answer. The strongest evidence for integrality was obtained in the selective adaptation studies with spatial frequency and orientation. Generally speaking, evidence suggests that stimuli undergo some early decomposition into some separable dimensional properties. However, selectively responding to values of some dimensions does not mean that they are seen independent of the object or background as free-floating values. Treisman (1986) suggested that this analysis may be built into the perceptual system, from the operational, strategic, special-purpose analyses that may be established through learning in particular tasks.

Since integrality and separability are supposed to occur at the functional level of stimulus processing, it does not seem reasonable to make inferences about them by the subjective assessment of the subject. Garner (1988) provided an elegant measurement of integrality-separability using a similarity/different task, although in some ways this measure was still based on a subjective assessment. According to this worker if reaction time to the comparison of two stimuli which vary across two dimensions is longer than the reaction time to a condition in which they share in any of the two dimensions, those two dimensions are integral. In contrast if RTs in the same and different conditions were the same, those two dimensions are considered separable. According to Garner, if results indicate no improvement for correlated dimensions, and full classification has the same speed as simple discrimination it will mean that stimuli are perceived to be composed of separable dimensions. However, if there is a gain in favour of the correlated dimension, that will mean that dimensions are perceived jointly. Garner suggested that 'selective attention' is only possible with separable dimensions.

It seems that stimulus dimensions affect the perception of the visual object. However, there are at least two approaches concerning the extent of this effect. According to the first approach it is the nature of the stimulus and its dimensions that constitutes the limits of integrality/analysability. For example, Ballesteros (1989) suggested that when

stimuli are made from integral dimensions, such as saturation and brightness, the performance of the subjects in a classification task is based on overall similarity, regardless of the type of instructions used in the task and the exposure time of stimuli. Ballesteros (1989) reported that from different dimensions used in her experiments, the dimensions of chroma and value are more integral than form and size. The extent of integrality of inclination-length was somewhere in the middle of the two other pairs. The results of the first experiment of Ballesteros (1989) indicated that objects constructed from form-colour are classified mainly by overall similarity, whereas those made up of form-size or inclination-length dimensions are preferentially classified by their dimensional properties. The dimensional classification with the more separable dimensions (i.e., form-size) was faster than the classification based on other dimensions. The speed of classifications was shorter with chroma-value materials than with other materials, such as indication and length, and form and size.

According to the second approach, the difference between integral and separate dimensions has been suggested to be task dependent. For example, according to Garner (1988) dimensions are both wholistic and analytic, depending on the task and stage of processing. Also it has been suggested that dimensions of shape and brightness are separable with speeded classification tasks but integral with a comparison (same-different) procedure (Santee & Egeth, 1980). Shepp (1989b) reported that perception of the integral stimulus was influenced by the task requirements. For example, physically integral stimuli which include properties such as shape, colour, and size are psychologically separable in unspeeded tasks, but are first perceived wholistically in the early stages of speeded tasks. Meanwhile, according to this worker there are two stages in the processing of dimensions: dimensions are integral and unanalysable at the primary sense, but they are analysable at the secondary phase.

In summary, the distinction between integral and separable dimensions, was originally proposed by Lockhead (1966), Garner (1970, 1974), and Garner and Felefoldy (1970), seems to be very useful regarding global precedence hypothesis. It appears that integrality and separability constitute a continuum in which the two extremes are integral

and separable poles. Factors such as dimensional complexity and task demand affect the integrality and analysability of dimensions. For example, an increase in the number of dimensions tends to produce classification based on overall similarity, whereas when stimuli consist of a few number of dimensions, they were classified by their dimensional structure (Ballesteros, 1989). Meanwhile, it was suggested that the capacity to attend selectively to one stimulus dimension depends on the experimental task (Duncan, 1985). For example, Ballesteros (1989) stated that variations in the task affect the perception of dimensions. Integrality and separability of dimensions may be also influenced by developmental aspects (Shepp, 1989a). For example, according to Shepp (1989a) some dimensions which are perceived as separable by adults are seen as a whole by young children.

However as an overall trend, stimuli varying along integral dimensions are seen as unitary entities, and those varying along separable dimensions are perceived in terms of distinct dimensions or attributes. One method of differentiation between the two kinds of dimensional relationship is a constrained classification paradigm. In this method, subjects are required to classify stimuli according to a dimension (Shepp, 1989a). Integral dimensions are defined as those when combined redundantly, speed and the accuracy levels of discrimination increase, and a decrease in speed and accuracy of classification occur when they are combined orthogonally. Height and width of a rectangle can be an example of a pair of integral dimensions. Separable dimensions, according to Kimchi and Palmer (1985), are those that produce no interference when combined orthogonally, and no facilitation when combined redundantly.

There are disagreements about the type of metrics associated with similarity judgment tasks (See Shepp, 1989b for a review). However, there are two fundamental points regarding the integrality of stimuli in unspeeded tasks: Integral stimuli are not perceived as subjective dimensions, whereas separable and separate figures are perceived so (Shepp, 1989b). Second, in speeded tasks it is assumed that if the stimuli are integral, variation in one dimension affects perception of the other dimension. Therefore, the speed of classification of integral dimensions is higher than the speed of classification of

separable or separated stimuli. Meanwhile, it is hypothesised that features of an integral stimulus are combined early in visual processing. However, the analysis of an integral stimulus into its component features does not mean that the features have all the properties of physically separable dimensions. Generally the divisibility of a visual scene depends on the type of components and the relationship among the components, including the distance among them. For example, dimensions such as hue, brightness, and saturation or colour are hardly separated and analysed. Meanwhile, as the distance between component parts decreases the efficiency of 'selective attention' in comparison to 'divided attention' decreases (Pomerantz, 1981).

1.3.4 Parallel and Serial Processing of the Whole and Parts

On any occasion that we choose between two stimuli or levels of a stimulus it may be argued that if the choice is made on the basis of information about one property, this delays the choice of the other property. This order may have considerable influence on the out-come of the final choice. In such a condition the question of concern will be what are the kinds of properties that can be or are ordered for evaluation, and what determines the order? Meanwhile, it is important to distinguish between stages of coding and the order of the introspective access to information. Wholistic or analytic processing may occur as two stages of processing without temporal order, or they may occur sequentially.

Parallel processing refers to a condition in which information from several intra- and inter-modal sources can be processed simultaneously (Duncan, 1980). The wholistic and analytic processing can be conducted both in serial or in parallel. However, there is a suggestion that (e.g., Treisman, 1986) wholistic properties may be more salient than separate dimensions, without necessarily reflecting an early stage of neural coding. Kahneman and Henik (1981) proposed that in the early stage of processing a stimulus is parsed into tentative objects (Kahneman & Henik, 1981). Perhaps parallel to this stage a functional equivalent of a parallel search occurs, which may result in directing attention to a target (Lennie, 1980). Some other workers (e.g., Hawkins & Presson, 1986) proposed that serial and parallel processing belong to different stages of visual perception. That

means up to a certain point visual information may be processed in parallel, beyond this point input seems to be processed sequentially. However, it seems that whether subjects employ serial or parallel processing is strongly task related (Kahneman & Henik, 1981). For example, there is some evidence that letter-digit distinction is available at preattentive level (Egeth, 1977).

Sperling and Doshier (1986) proposed that to the extent to which a perceptual property in a retinal location for example, the right visual field, can be compared to the memory representation of the target while another property in another part of the field is being compared to a representation of another target relates to the parallel processing capacity of perception. On the other hand, the extent to which such a comparison draws from a common pool of resources represents processing which occurred serially. Unequivocal establishment of serial processing could imply separability. On the other hand, parallel processing could be integral or wholistic, although it does not need to be (Treisman, 1986). The paradigm which is usually used in this type of study is a same-different matching task. The number of dimensions on which stimuli vary or the number of similar dimensions is measured. A linear increase in response latencies with number of relevant dimensions is interpreted as reflecting serial processing and separability of dimensions (Treisman, 1986).

Generally it seems that parallel-serial processing is highly depended on the physical properties of the stimuli and task demands. In a visual search task, searching for a target defined by only one dimension seems to employ a parallel (preattentive) processing. In fact, search is not affected by set size effect. On the other hand, conjoining of features as a process usually requires attention, and needs serial processing (Treisman, 1988). The difference between features and dimensions results in two different modes of processing. Processing of the stimuli made of features is based on feature recognition and seems to be in parallel. It appears that the speed and accuracy of identification of feature-defined stimuli are more efficient than dimensionally-defined stimuli. On the other hand, the identification of two targets which have the same level on a dimension is parallel, but the identification tends to be serial if the targets involve two levels on the same dimensions

(Garner, 1978a). The literature on part-whole relationship is also intertwined with the issue of top-down versus bottom-up processing. In the following section these concepts will be discussed.

1.3.5 Top-Down Versus Bottom-Up Processing

The idea of wholistic/analytic processing is somehow mixed with the concept of top-down/bottom-up processing. The latter is used in two distinct senses (Treisman, 1986). In one sense top-down or bottom-up processing is used in the same way as wholistic/analytic processing. That is top-down processing refers to processing which initiates from the whole and proceeds towards breaking that whole into its components, and bottom-up refers to processing which starts from component properties and progressively precedes towards the whole. For example, some workers such as Kinchla, Solis-Macias, and Hoffman (1983) and Kinchla and Wolfe (1979) suggested that structural relationships between global and local levels of a compound shape can be seen as a sign of or explanation of modes of processing. These workers used the terms top-down versus bottom-up, and wholistic versus analytic interchangeably.

In the second sense, the top-down/bottom-up dichotomy corresponds to the concepts of conceptually-driven and data-driven processing (e.g., Gibson, 1969; Gopher & Kimchi, 1988; Lindsey & Norman, 1977; Rumelhart, 1979). According to this view, the term top-down refers to processing in which prior knowledge or expectation about an event or an object leads to the recognition of that stimulus. That means perceptual processing originates from the hypothesis which has been made by a perceptual system and then the data are analysed accordingly, based on the hypothesis which was provided by the system. In fact, it corresponds to a perceptual mechanism which is constrained by the hypothesis or the strategy generated by the system and not by the nature of the input data. For example, top-down perception, according to Gibson (1969), is built into all levels of perceptual systems as a result of evolution, so that even sensory receptors are designed to detect action-relevant object properties rather than pure physical properties such as wavelengths, or auditory frequencies. In contrast, bottom-up processing refers to

processing in which the meaning of a perceived stimulus is constructed from the stimuli impinging on the perceptual organs. In other words, bottom-up processing in this context refers to data-driven processing in which the percept is constructed primarily from the stimuli and not by the hypotheses about the nature of the input.

Generally speaking, bottom-up processing suggests that visual perception is derived from the information transferred from the visual object. Because of the possibility of the detection of some physical relationships such as support and interposition of objects without the identification of bodies, some workers (e.g., Biederman, 1981) have argued that this kind of information is extracted before object identification. This bottom-up, physical-then-semantic view is based on the assumption that the features of the different parts of a scene are processed prior to the processing of whole view. The information extracted by the visual system at this level is used to identify both the physical parts of the scene and the whole object (Biederman, 1981). On the other hand, top-down processing is concerned with applying constraints from memory to organise the percepts (Chase, 1986).

Apart from these two extremes, there are some other intermediate views. The Gestaltists proposed that the properties of perceptual experience are neither "from the bottom" nor even "from the top" alone, but must be explained simultaneously at all grains of analysis (Shaw, 1978; Shaw & Turvey, 1981). It seems that top-down/bottom-up matching to familiar categories is not a unidirectional process but, is an interaction in which sensory information makes contact with cognitive information. Of course, the richness of the sensory information is so redundant and strained that it imposes the least amount of attention to control feature integration (Treisman, 1986). On the other hand, it appears that whether a stimulus originates from sensory information or from an internal hypothesis does not necessarily imply a temporal precedence or any type of interference of one of the structural or perceptual levels. For the sake of clarity it seems better to use the concepts of top-down/bottom-up processing for conceptually driven versus data driven rather than wholistic-analytic processing (Kimchi, 1992). That is how the terms will be used in this thesis.

1.3.6 Classifications of the Part-Whole Relationship

The concept of whole is defined, classified, and used in various ways. In this section I will describe a number of classifications that have been suggested in the literature. These classifications will be evaluated all at the end of this chapter. The chapter will be concluded by the proposal of a new classification of part-whole relationship. Generally there are two different usages of this concept (Kimchi, 1992). According to the first application, the terms wholistic and global processing are used interchangeably referring to the primacy of perception of higher structural levels to parts or local components. This view seems to be in the spirit of Gestalt Psychology. Navon (1977, 1981a, 1981b, 1991) and many other workers (e.g., Lasaga, 1989) who have studied the global precedence hypothesis have not differentiated between the concepts of whole and global, and parts and local components.

The other usage, according to Kimchi (1992), refers to the differentiation between the unitary whole and its properties (whether wholistic or component). To have an idea of what unitary whole means in this context, Kimchi provided the example of the similarity of two faces regardless of the colour of eyes or the shape of nose. According to this view, the unitary whole is the primary unit for processing (e.g., Smith, 1989). The primacy of wholistic properties suggested by the first view may be considered as analytic processing from the second view. Wholistic unitary in this usage seems to have a mystic entity. In fact, it is not clear what would remain as the whole if properties of a whole are crossed out. In the next section of the present study I will explain the reasons why I prefer the concepts global and local to whole and parts. However, before that some common definitions and classifications of wholistic and global properties will be reported.

Kimchi (1992) defined global and local properties by their positions in the hierarchical structure of the stimuli, and wholistic properties as a function of relationships among component parts. According to this worker, wholistic properties depend on the interrelations among the components of an image (Kimchi, 1992). These properties do not exist in the parts and cannot be inferred from considering just the component parts.

This definition of the concept of whole is similar to what is referred to as emergent properties in the literature. In continuation of this section we will have a close inspection of the concept of emergent properties.

1.3.6.1 Emergent Properties

How the perceptual system performs the task of synthesising information is an important problem in the study of perception. Grouping of parts into an integral whole or a configuration is operationally defined as an inability to concentrate attention on one individual component. Meanwhile, in 'divided attention' tasks the preference for wholistic properties is interpreted as the precedence of wholistic properties in information processing. One of the outcomes of perceptual grouping may be the creation of properties out of interactions of components, which are called emergent properties (Garner, 1978b; Pomerantz, 1981). Emergent properties are defined as properties which are not directly presented in parts but are the outcome of their interaction (Pomerantz, 1981). It is assumed that emergent properties are the product of direct processing and they are not perceived via the recognition of the component properties. That means these properties possess features that their components do not. Subjective contours provide a good example of an emergent property because the subjective contours seem to emerge from the interpretation of the whole object (Treisman, 1986).

Wholistic properties such as symmetry and closure have been also called "emergent" (see, Garner, 1978b; Kimchi & Goldsmith, 1992; Pomerantz, 1981). Despite, the literal meaning of "emergent" there is no need for them to be derived from their component properties. In contrast, the concept "emergent" implies that these properties do not exist in component properties but rather they "emerge" from their interrelations. Some workers (e.g., Kimchi & Goldsmith, 1992; Lasaga, 1989) have suggested that emergent properties are extracted at an early stage of processing. For example, Pomerantz (1981) reported that figures such as triangles are more discriminable than the lines comprising them.

Treisman and Paterson (1984) demonstrated that, in a 'selective attention' condition, illusory conjunctions are more frequent when the characteristic of closure is present in the display together with the component segments than when it is not. For example, when the task is the detection of a target shape such as a triangle, the presence of a shape such as a circle, whose components are not the same as the segments of a triangle but which has the property of closure in common with a triangle will facilitate the perception of the triangle. From these findings Treisman and Paterson (1984) concluded that an emergent feature is not produced by combination of components but is extracted as a simple property and is available at the stage of early extraction of stimulus properties.

Garner (1978a), also suggested that emergent properties may be extracted directly from stimulus input. Similar to Garner (1978a), Kubovy (1981) reported that stimuli are organised regardless of how they are perceived, and they are composed of parts, relationships among parts, and of attributes over which the parts are distributed. Kubovy called the relationship among parts configural properties. Since these properties depend on relationships among parts, they cannot be changed without changing at least some of their parts. According to this definition a property such as symmetry is a configural property because it is not possible to move the axis of symmetry without shifting the parts. The reason Gestalt psychologists proposed that whole is more than or different from the sum of the parts is that they perceived configural properties as parts plus the relationship among them.

An emergent property is not something which may occur independent from physical properties of the stimulus and task demands. There is strong experimental evidence suggesting that some physical configurations enhance unitary perception and failure of successful 'selective attention' to some constituents rather than others. For example, Pomerantz and Garner (1973) in a speeded classification task indicated failure of 'selective attention' to parts using combinations of right and left parenthesis, ((,)(, (),)). Grouping of elements into a unitary whole in the 'selective attention' condition is a measure of the strength of the whole. Some studies (e.g., Palmer, 1975; Pomerantz & Garner, 1973) have suggested that unitary perception of a pattern depends on the level of

redundancy of the emergent pattern. In a discussion about grouping, Pomerantz (1981) emphasised the unity of the perceptual pattern. He proposed that wholes are perceived independently of the processing of their parts. Talking about configural superiority Pomerantz proposed that context can either improve or impede performance, depending on the emergent configuration. When one of the two parentheses was rotated 90°, or was placed further apart from the other, the configural interaction was destroyed. Failure of 'selective attention' to the components of a pattern reflects deliberate attention to emergent features (Pomerantz, 1989). According to these workers, emergent features are more salient than component features in affecting the performance.

Emergent properties are not spatially local properties, in the sense that parts are local (Pomerantz, Pristach, & Carson, 1989). Properties such as closure and symmetry are distributed throughout the visual object. Using the terminology used in the spotlight hypothesis (e.g., Eriksen & Eriksen, 1974; Eriksen & Schultz, 1977, 1978, 1979; Eriksen, St. James, 1986) it can be said that to perceive an emergent feature attention has to be spread throughout the object. Therefore, in a spatial sense emergent properties have to be global or wholistic. Here, global or wholistic refers mainly to the spatial extension of an object. Otherwise, according to Pomerantz, Pristach, and Carson informationally an emergent feature is analytic rather than wholistic (Pomerantz, Pristach, & Carson, 1989).

It has been suggested that emergent features are more discriminable from one another than are parts. For example, Pomerantz, Pristach, & Carson (1989) showed that () and)) are discriminated from each other easier than (and). This is also known as the configural superiority effect (Pomerantz, Pristach, & Carson, 1989). According to this approach slower processing of parts in comparison to emergent features is not because of a barrier or interference which is produced by local properties, but is the result of facilitation which is created in favour of the emergent features. This concept is in contrast to the view that portrays perception as a closed system (e.g., Navon, 1977; Navon & Norman, 1983). According to the latter view perception of the whole and parts operates as a closed system, i.e., any change in the reaction time to either of the levels is associated with a counter effect on the other level. For example, when whole properties were

processed faster than their parts, it means that the parts were processed slower than the speed which they would be processed if they were displayed individually. In fact, according to this approach a gain in one level is associated with a loss in the other. In contrast workers such as Pomerantz, Pristach, & Carson (1989) proposed a type of relationship in which a gain at one level is not necessarily accompanied by a loss in the other. I will investigate this issue experimentally.

As was already mentioned, emergent is defined as a property which does not exist in any of the individual parts of a visual stimulus, but results from the interaction of parts. Symmetry and closure are usually given as the examples of emergent properties (e.g., Garner, 1978a; Pomerantz, 1981). However, what is called an interaction does not seem to be more than the spatial arrangement of the component parts. In fact, that mysterious property which is added to the whole is the figure made by the spatio-temporal arrangement of component parts. Thus, it may be questioned that if closure made by the intersection of three lines is an emergent property, why cannot any other figure made up of the spatial arrangement of some figures, such as a large letter made up of suitable arrangement of small letters be considered as an emergent property. Based on the definition provided above of the emergent properties, any figure made up of the spatio-temporal arrangement of some other figures should be considered an emergent figure. Therefore, limiting the notion of emergent properties to properties such as symmetry or closure does not seem reasonable. However, the most important point is to discover the reason for this confound in the literature. It appears that the problem arises from individuals' extensive familiarity with some properties such as closure, which probably enables them to respond faster to such properties than other unfamiliar ones. In fact, responding to the former properties seems to occur through automated channels while the latter properties are processed by some controlled ones. Therefore, the locus of emergent properties seems to be mainly in the subject's better familiarity with some configurations than the others. In summary, any visual property composed of the spatial and/or temporal arrangement of some local properties produces an emergent dimension or feature. However, emergent properties vary according to their redundancy level. Obviously, the

speed of recognition of familiar emergent figures is faster than unfamiliar ones. As was mentioned previously, integrality and separabilities of components play an important role in the quality of the emergent figure. However and more importantly, integrality and separability of the component properties are determined by the limitations of neural hardware of the human perception. For example, the sensation of motion caused by the successive display of figures, or the spatio-temporal composition of the colours is determined by the physiological limitations of the human perceptual mechanism. Kimchi's (1992) interpretation of part-whole relationship has strong similarity with the concept of emergent property. This classification will be presented in the next section.

1.3.6.2 Kimchi and the Number and Size of Elements

Kimchi (1992) seems to adopt a Gestaltist approach towards the part-whole relationship. According to her the main thrust of wholistic properties is that they do not exist in components. Wholistic properties depend on the relationships between the component parts (Kimchi & Goldsmith, 1992). One sense of wholistic properties, according to Kimchi, is that their speed of processing is faster than component properties. Kimchi (1983) studied the validity of the assumption that there are two distinct perceptual levels corresponding directly to the global and local levels of stimulus structure. Perceptual organisation of compound shapes was tested through similarity judgment, verbal description, and speeded classification tasks. The results indicated that parts (local components) of compound patterns made up of few relatively large elements, were perceptually salient as individual parts of the global configuration. Increasing the number of elements accompanied by decreasing their size resulted in the perception of a unified form associated with a texture. In the latter condition perceptual salience of the local figures decreased. From these findings, Kimchi (1983) suggested that mapping of the two distinct geometrical levels into perceptual levels depends on the number and size of the elements. These results imply that the perception of a whole depends on the geometrical structure of the stimulus.

Kimchi (1992, 1983) and his associates (Kimchi & Palmer, 1985) therefore classified stimuli according to the relative size and number of their local elements. They suggested that when a pattern consists of many small elements, the local elements are perceived as a texture and the global configuration as a form. However, when a pattern is composed of few large elements, both global and local levels are perceived as forms. Kimchi and Palmer (1985) suggested that these two types of compound stimuli differ according to their integrality/separability. The global and local levels of many-element stimuli seem to be separable. That means replacement of component parts by other elements does not appear to affect the perception of the global level. However, replacing the elements of a few-element pattern seems to affect the perception of the global level.

In another study Kimchi and Palmer (1985) employed a speeded classification paradigm to examine the relationship between the global and local levels of two types of patterns: those consist of a few relatively large elements and those composed of many relatively small elements. The results again demonstrated that the perceptual relationships between the global and local levels depended on the number and the relative size of local components. In many-element stimuli, when patterns were processed in terms of form and texture, the global and local levels seemed to be perceptually separable. The global configuration and the local component were processed differently as a discrete form and as a texture, respectively. However, the global and local levels of few-element stimuli appeared to be processed by common mechanisms and thus might interfere with each other. The results of Kimchi and Palmer's experiment indicated that in a speeded classification task the global and local elements of few-element patterns were perceptually integral. This was concluded from the fact that RTs to the local elements were not affected by the dimensional instruction. Again, the integrality of the global configuration and local elements in this type of task demonstrated that the few element patterns were processed in terms of the form and figural parts. However, the two levels of the many-element stimuli were processed in terms of forms and texture. Therefore, the same physical properties, global and local levels, are not treated perceptually the same in many-element and few-element patterns. From these findings, Kimchi and Palmer (1985) suggested that since the

global configuration of many-element patterns interact differently with a texture and with a local form, it is necessary to specify which features or aspects of the global and local levels are considered when testing a global advantage effect. They proposed that neither the global configuration nor local component of the many-element pattern is processed prior to the other. According to these workers, concerning the Gestalt notion of the priority of wholes over their parts, few-element patterns seem to be better candidates for testing this hypothesis. Another classification of part-whole relationship is presented in the next section.

1.3.6.3 Garner's Classification

By choosing the English wholistic rather than the Greek holistic, Garner (1978a) divided wholistic properties in three main categories: simple wholes, templates, and configurations. In Garner's terminology stimuli can be described according to their components. However, if a stimulus is described according to all of its components, then in a sense it is described as a whole. According to Garner this kind of whole is not more than or different from the sum of its parts. It is an information processing concept and it refers to a condition in which all the parts are processed in parallel and therefore, as a whole. The term template is mainly used in the information processing literature to exemplify wholistic processing in contrast to component processing. Similar to the concept of simple whole it does not convey any positive stimulus property to the template that does not exist in the components. Configuration wholes are those that can be expressed without reference to their component parts. According to Garner, this type of whole is more than or other than the sum of the parts. It refers to the relationship between parts, e.g., symmetry and repetition. Garner proposed that configural properties are cognitively more salient than component attributes. Meanwhile, component and wholistic properties are dependent on each other, and wholistic properties are the consequences of the interrelation of attributes. Garner proposed the possible importance of configural properties in psychological processing on component attributes. He suggested that the order of processing can be measured best using stress tasks. The speed of processing in

this type of tasks can be used as the measure for the order of processing. There is not much elaboration on the relationship between classification of wholistic properties, mentioned in this section, and the concepts of integral and separable dimensions and features in Garner's work. However, Garner's classification provides a suitable background for more detailed discussion on part-whole relationship. This will be indicated in section 1.4.1.

1.3.6.4 Pomerantz and Type-N and Type-P Stimuli

Pomerantz and Kubovy (1986) suggested that the problem of grouping and part-whole relationship is the major phenomenon of perceptual organisation. It is assumed (Pomerantz & Kubovy, 1986) that the global shapes are compiled by grouping the constituent parts into higher order structures. Pomerantz (1981) and his associates (e.g., Pomerantz & Kubovy, 1986) distinguished between two types of perceived wholes according to the nature or position of the local information which is used to process the global level: Type-P and Type-N. In Type-P stimuli, the perception of the whole depends only on the 'position' of the local units. In type-N patterns, not only the position of local elements but also their 'nature' is important. The typical stimuli used in the global precedence hypothesis, large letters made up of small letters, can be considered as type-P patterns. However, a pattern such as the letter "T" in relation to its horizontal line segment at the top is considered as a Type-N configuration, because, if it's top feature was changed to a dot, the global configuration will change to the letter "i." Pomerantz indicated that the these two types of configurations embed different types of perceptual relationships.

Robertson and Lamb (1991) similarly emphasised the role of nature and position of the component parts. These workers suggested that it is not always the nature of the local elements which determines the global identity, whereas it is their position. An eye certainly suggests a face, but one does not need to perceive the nature of the parts to perceive a face. For example, three dots located appropriately in a circle will be seen as a happy face. In fact, Robertson and Lamb (1991) did not say that the nature of the

elements is not important but they suggested that position information is important as well. An earlier classification of local properties proposed by Pomerantz and Kubovy (1981) fits well with the concepts of Type-N and Type-P stimuli. A short explanation of that earlier classification will come now.

1.3.6.5 Spatial and Hierarchical Local

Pomerantz and Kubovy (1981) provided two definitions or classifications of the term local. According to the first definition local refers to limited regions of the visual field. They called this type of local 'spatially local.' Subjective contours were not considered as examples of the spatial local because they are created by interaction over a broad distance. Based on the second definition the concept of local refers to a low level in a hierarchical system. Pomerantz and Kubovy called this sort of stimulus, 'hierarchical local'. They suggested that subjective contours can be considered as the example of this type of local. The 'spatially local' and 'hierarchically local' fit with Type-P and Type-N stimuli, respectively. A similar classification of part-whole relationship was suggested by Lasaga (1989).

1.3.6.6 Lasaga and Type-C and Type-D stimuli

Lasaga (1989) suggested another classification of part-whole relationships. She referred to stimuli composed of physically connected local parts as Type-C stimuli, and those composed of physically disconnected locals as Type-D stimuli (Figure 1). It seems that Type-D and Type-C stimuli are similar to Pomerantz's Type-P and Type-N stimuli. Large letters composed of small letters, which are used in the global precedence hypothesis (e.g., Kinchla & Wolfe, 1979; Navon, 1977; Navon & Norman, 1983), are examples of Type-D stimuli. Lasaga suggested that local and global properties of Type-D stimuli are processed in parallel, and information precedence is determined by the relative discriminability of properties. However, with Type-C stimuli wholistic ('higher level') properties were processed before parts ('lower level properties'). For example, the identification of a line within the context of some other lines is better than performance

with the same lines in isolation. This has been called the object superiority effect. From the facilitation in the processing of parts in Type-C stimuli when they are embedded within a context, Lasaga concluded that the global or wholistic properties are processed prior to the parts.

(a)

(b)

Figure 1. A sample Type-C (a) and Type-D stimuli (b) (Lasaga, 1989).

Meanwhile, from the finding that the addition of a context to a single line improved the performance to that line as the part of the Type-C stimuli, Lasaga proposed a model of sequential processing in which the processing of the global level preceded the processing of the parts. She also found that the discrimination of a pair of Type-C stimuli is faster when they did not have common wholistic properties, irrespective of the discriminability of their component properties, and classification of these stimuli is easier according to their wholistic properties than component properties. Thus, she concluded that the processing of wholistic properties dominates component properties. According to this worker if the global and local levels were processed serially, the discrimination of tasks sharing a property at the global level should be harder than the tasks which do not share any properties at that level. The results of her study indicated that in a discrimination task with Type-C stimulus, processing of the global level precedes the local level. Lasaga (1989) also reported that the classification according to an emergent property such as closure/intersection was faster than classifications based on local properties.

1.3.6.7 Semantic Relationship

Apart from the structural relationship of the whole and parts, these two levels may have semantic relationships with each other. The semantic relationship in this research refers to any type of natural or conventional association of the identities of the two levels. For example, a boat has a semantic relationship with the global configuration of a sea shore and not a forest. Studies on the global precedence hypothesis have usually avoided conducting experiments with this type of semantic relationship between global and local levels. The reason for the lack of interest in this type of stimulus originates from normal redundancy (correlation) between the whole and parts of this type of compound patterns. A face is more likely to contain eyes, just as eyes indicate the presence of a face. Thus the perception of a visual image can be strongly affected by the scene in which it is embedded (Kinchla, Solis-Macias, & Hoffman, 1983). The main reason to use the type of experimental stimulus illustrated in Figure 1b, large letters composed of small letters, is to avoid the confounding effect of this redundancy. However, the redundancy or the semantic relationship between whole and part, according to the terminology of the present study, is part of the reality of human perception and cannot be ignored, totally. Apart from semantic relationship which exists between the properties of natural views, there may be some sort of conventional relationship of the Stroop type between the two stimulus levels. This type of semantic relationship is usually caused by response association between the two levels. For example, using large letters composed of small letters as the stimuli, if the target letter occurs either in the global or local level, there may be some sort of conventional semantic relationship between the two levels due to the consistency or inconsistency between them. It does not seem that there are many studies on the natural semantic relationship between the levels of the compound pattern. The only one which will be mentioned in this research belongs to Antes and Mann (1984) who found a reversal in direction of 'globality' according to the size of stimuli whose global and local aspects had a semantic relationship with each other. From this result they

concluded that perceptual grouping of the type proposed by Pomerantz (1981) did not occur with the stimuli whose parts and whole had a semantic relationship with each other.

1.4 The Concept of Whole: A Summary and Criticism

Although in the last two decades or so, the Gestalt view of perception, excluding their physiological approach, has again become prevalent among psychologists (e.g., Kimchi, 1992; Kubovy & Pomerantz, 1981; Shepp & Ballesteros, 1989), unfortunately a clear definition of the concept of whole has not been provided. In the previous sections some definitions of part-whole relationship and various classifications of wholistic properties were introduced. Perhaps the most distinct aspect in the part-whole relationship is that wholes have specific properties that lead to a performance different from their dimensional and featural properties and parts (Dixon & Just, 1986; Shepp, 1989b). Growing interest in the Gestalt view has revived works on issues such as perceptual grouping, global/local processing, and increasing usage of the term wholistic rather than analytic (See Kimchi, 1992, for a review). However, there has been some confusion in the literature regarding wholistic properties. The concept of whole is usually used in a loose way without much theoretical clarification or operational definition. Meanwhile, there is not much agreement among different workers on classification of wholistic properties.

The geometrical structure of the stimulus does not necessarily correspond to the nature of the perceived dimensions, features, and parts. A dimensionally defined stimulus may be processed as features, and vice versa as outlined earlier in this chapter. However, since the perceptual properties of dimensions, features, and parts are different, processing based on features may be different from processing based on dimensions or parts. For example, Garner suggested that overall concept learning is easier with stimuli which are generated from dimensions rather than from features. He also distinguished between the 'selective attention' to the source of variation in a dimension and the levels in a dimension.

Meanwhile, there is not a clear cut distinction between the wholistic-analytic dichotomy and top-down versus bottom-up processing. Some workers (e.g., Caelli & Dodwell, 1982; Kinchla & Wolfe, 1979; Kinchla, Solis-Macias, & Hoffman, 1983) have used these concepts interchangeably. The dichotomy of wholistic/analytic must be differentiated from top-down/bottom-up processing. The latter concepts are best used to refer to the distinction between "conceptually driven" and "data driven" processing (Pomerantz, 1981; Warner, 1981). Although some workers such as Kimchi (1983, 1992) suggested that whether the origin of processing is from perceptually constructed concepts or from stimuli, is not directly related to the precedence of wholistic/analytic dichotomy, it seems that when processing begins from some conceptual structures, subjects have a better chance of wholistic than analytic perception. In fact, previous knowledge which may originate from conceptual structures seems to be in a wholistic form. The process of concept formation seems to be associated with some sort of elimination of the difference in parts. Generally a grouping operation which begins with a conceptually driven hypothesis, or the expectancy to see a good shape may facilitate the processing of simple or good figures, and a grouping operation which starts from data may be differentially inclined to process the stimulus Gestalt.

Human perceptual organisation has a limited ability of processing a single dimension with several objects simultaneously whereas it is able to process in parallel multiple dimensions of a single object (Kahneman & Treisman, 1984). Serial/parallel processing seems to be related to the quality of stimulus properties. When two targets have no difference in levels on two dimensions, they will be processed in parallel. However, if two stimuli have two levels on the same dimension, the evidence is in favour of serial processing (Garner, 1978a). Meanwhile, it appears that stimuli generated from features are likely to be processed in parallel, but parallel processing of levels on a dimension is not possible (Garner, 1978a). One of the issues regarding to the part-whole relationship is if parts and wholes are processed in parallel or serial, and in any case what the relative speed of processing of the two levels is.

The encoding of wholistic properties should be distinguished from identification of the whole as such. Meanwhile, order of processing of stimulus properties is probably related to stages of processing. Treisman (1986) suggested three possibilities in which processing of a whole may precede its details. First, it seems that there is some early parsing of the scene into objects and backgrounds. The processing of each of these areas is global in the sense that only their boundaries and locations are defined. Second, the whole may have quicker access to conscious awareness. In other words, it may be easier for us to see some events of specific arrangements, such as a laughing child while catching a ball. Finally, the perceptual system tends to detect rational properties that define objects and events, rather than those which physicists define. This fact is compatible with the early separation and analysis of these real world properties.

The concepts of global and wholistic are sometimes used interchangeably. However, some workers (e.g., Garner, 1978a; Kimchi, 1992; Kimchi & Palmer, 1985; Navon, 1977, 1981b, 1983; Rock, 1975, 1986; Pomerantz & Pristach, Treisman, 1986) have distinguished between these two terms. According to this approach the wholistic or emergent properties result from the relationship among parts and they refer to properties which do not exist in the individual components of the compound stimulus. It seems that part of the ambiguity in part-whole or global-local relationship emerges from the variety in types of compound patterns and the relationship among their components and the relationship between the components and the global configuration. Properties such as various dimensions, features, and parts may bear different relationships within and between each other. Therefore, definition of the whole as an emergent property does not seem to be an operationally clear definition.

The main premise underlying the study of hierarchical patterns is that the geometrical structure of the stimulus corresponds directly to distinct perceptual units that differ in their level of globality. Therefore, although local and global levels of a stimulus are geometrically independent, whether they are perceptually independent is a matter that has to be examined empirically. Physical and psychological properties of compound stimuli and their relationship were considered in detail in the previous sections. It was

indicated that geometrical and psychological properties do not necessarily correspond to each other. Thus the relationship between whole and parts may vary according to the physical structure of the stimulus and task demands.

The global precedence hypothesis began with an assumption that the global and local components are perceptual units of compound patterns. For example, Navon (1977) suggested that since local elements can be perceived as separate entities they constitute units of visual perception, as well. However, Kimchi (1983, 1992) and his associates (e.g., Kimchi & Palmer, 1985) proposed that the percepts of local elements of the many- and few-element stimuli are different, although the local elements of both types of stimuli seem to be recognisable. Garner (1970, 1974) classified visual stimuli as "integral" or "separable." According to this classification, integral dimensions are perceived unitarily and a change in any of their levels seems to produce a qualitatively different stimulus. However, stimuli varying along separable dimensions are perceived as having distinct properties. Pomerantz (1981) classified visual stimuli according to the relationship between the identities of whole and parts to Type-N and Type-P patterns. Lasaga (1989) reported experiments with what she called Type-C and Type-D stimuli, referring to the stimulus whose parts are connected in contrast to the one with disconnected components.

1.4.1 A New Classification

Navon (1981a), correctly, proposed that the global precedence hypothesis cannot be studied unless the perceptual units are known. In a condition that there is not such knowledge he suggested that common sense reinforced by the Gestalt laws is a reliable source. However, using the present level of knowledge on visual processing, it seems possible to provide a more precise and comprehensive classification of the part-whole relationship than what has already been suggested.

It seems that the ambiguity in the part-whole relationship has partially resulted from the fact that the terms part and whole are intertwined with some philosophical background as well as, theoretical concepts referring to top-down and bottom-up processing. Therefore, in the present study I will limit myself to the usage of the terms global/local

precedence to refer to the theoretical account of wholistic/analytic modes of processing. Meanwhile, borrowing the concepts initially used by Kimchi and Palmer (1982), throughout this research the following terms will be used to describe the hierarchically structured patterns: local properties or local components referring to dimensions, features, or parts which constitute a stimulus; the global configuration or global level referring to the figures encircle the local components and are usually composed of certain local properties; and the hierarchical or compound pattern referring to the entire stimulus figure. The distinction between global configurations and hierarchical patterns seems to be useful, because the global configuration does not refer to local elements, whereas a hierarchical or compound pattern refers to both levels at once.

The review of literature on compound patterns reveals that none of the classifications of 'wholes and parts' relationship mentioned in the previous sections of this thesis provided an adequate explanation of processing of the global and local levels. It was explained that the definition of the concept emergent as the property resulting from interrelationships among the local component cannot be limited to a special type of stimulus. Perhaps, the most distinct aspect of the classifications suggested by Kimchi, Pomerantz, and Lasaga is their emphasis on the role of relative size of the two levels in the perception of the compound patterns. However, apart from this useful finding, there is little attention to wealth of literature on the role of object properties (i.e., features, dimensions, and parts) proposed by workers such as Garner (1974) and Treisman (1986). These workers have indicated that dimensions, features, and parts are perceived differently. Therefore, it seems reasonable to suggest that the global and local levels of compound patterns of dimensional and featural relationship may be perceived differently. In this concluding section of the present chapter a new classification of global-local relationship is provided. This classification is based on the review of literature mentioned in previous chapters on object properties, and separable and integral stimuli.

The concepts of the global and local and the attributed relationships between these two vary in different experiments and among workers. In the crudest sense global and local may refer to the outer and inner features of a visual object which have *inclusion*

relationships with each other. That means the most distinct aspect of their relationship is that one is located inside the other. In this sense the local is not a dimension, feature, or a part of the global configuration in the sense that the line segments make up the form of a letter. In this type of global-local relationship the global level acts as a frame surrounding local components. It seems that such a frame affects the perception of a surface and increases the coherence of contours of a stimulus located within the frame (Wenderoth & van der Zwan, 1991). Gillam and Broughton (1991) studied the effect of an ambiguously rotating frame on a pair of ambiguously rotating lines within it. The results of their experiment indicated that perceptual coherence among enclosed lines is increased by a frame when the lines had perspective approximately consistent with the frame. These workers suggested that the coherence produced by a frame was related to the global form (the frame) and not to the local grouping between the contours and individual lines of the frame. In fact, frames were involved not only in the encoding of objects for recognition and in providing information about size, orientation, or motion, but also they are important in the formation of perceptual units that can undergo other processes such as the process of forming a set of lines into a unit.

The second possible relationship may be called a *placeholder relationship*. In this type of stimuli the so called global configuration is made of the spatial arrangement of the local elements but, the former level does not depend on the identity of local elements. For example, Miller (1981, 1987) proposed that responding to the global configuration of a large letter was not influenced by changing the orientation of local components. In fact, in this type of relationship the local components not only are located inside the outer contours of the global configuration, but also they are as the breaks constructing the global configuration. The typical stimulus used in the global precedence paradigm, a large letter composed of small letters, is the best example of this type of global-local relationship. In this type of compound pattern, global and local levels can be manipulated independently. Therefore, the local elements are merely placeholders (Antes & Mann, 1984). Although the similarity of the identities of the levels may have an effect on the processing of the other levels (Duncan & Humphreys, 1989; Sagi & Julesz, 1987), the

configuration of the global level does not seem to be dependent on the identity of local components. Thus the global level seems to depend only on the spatial arrangement of the local components. Navon (1981b, 1991) proposed that large letters composed of small identical letters have equal complexity, recognisability, familiarity, codability, and relative diagnosticity. The use of hierarchical patterns of the placeholder type, similar to what was initially presented by Navon (1977) and Kinchla (1974), was seemingly well motivated not only because of the control of structural redundancy in this type of stimulus but also because of its usage in the everyday life. A group of flowers can define the border of a yard whether or not the individual flowers are seen. As Robertson, Egly, Lamb, and Kerth (1993) said, a group of leaves can define a branch regardless of the identity of the leaves, even when the branch is not in view.

In the third type of compound pattern, the global-local relationship is based on the perceptual grouping of local figures. Here, also there are both an inclusion and a placeholder relationship between the two levels. However, the global figure is made up of the perceptual grouping of local components and local elements function as the features of the global configuration. For example, line segments of an alphabetic letter are the features of that letter. This type of global-local relationship will be called a *featural relationship* throughout the present research. The fourth type of compound pattern refers to a stimulus whose global and local properties are related to each other based on a dimensional relationship, such as the colour of a visual stimulus. A review of the literature indicates that dimensions can be integral or separable. Therefore, a dimensional relationship may be based on integral or separable dimensional properties. Any of the above mentioned relationships may or may not be accompanied by a semantic relationship between the global and local levels. For example, a boat in the context of a view of a beach is not only inclusive regarding the hypothetical or real borderlines of the global figure, but also there is a semantic relationship between these two levels. The Stroop-type interference of the global and local levels refers to some sort of conventional semantic relationship between the levels.

Based on the review of literature mentioned in previous sections of this study, it seems that the global and local levels of the compound patterns suggested in my classification are perceived differently at the functional level of visual perception. In the present thesis the global precedence effect is studied using compound patterns of inclusion and placeholder relationships. Patterns of dimensional and featural relationship are not investigated in this thesis but are discussed as issues which require further experimentation.

Chapter 2

Global/Local Processing

2.1 What Is the Global/Local Precedence Effect?

As was mentioned in the previous chapter hierarchical patterns refer to the figures in which smaller objects are subsumed within larger objects (Lamb, Robertson, & Knight, 1989). A property of a hierarchical pattern which is considered as a global configuration on one occasion, may be viewed as a local property within another context. For example, a face is a global configuration in comparison to its parts, but it is a local component in the context of a body. A hierarchical pattern is an example of logical asymmetry between the two dimensions. The local elements logically can exist without a global configuration, but a global configuration cannot exist without local components. However, as Kimchi and Palmer (1985) proposed, despite this logical asymmetry the experimental results have not always demonstrated a dependency between the two levels. Whether human perception is organised such that the processing of global percepts precedes the processing of local elements is a major question in the psychology of perception. Global/local precedence hypothesis claims that a general, overriding set of rules governs perceptual organisation. This hypothesis usually refers to earlier or faster availability of information of either the global or local level in the process of formation of a percept (e.g., Navon, 1977, 1981a; Lasaga, 1989).

The global precedence effect has been the topic of many studies in the last two decades (e.g., Boer & Keuss, 1982; Hoffman 1980; Hughes, Layton, Baird, & Lester, 1984; Kimchi & Palmer, 1982; Kinchla & Wolfe, 1979; Lamb & Robertson, 1988, 1990; Martin, 1979a; Miller, 1987; Navon, 1977, 1981a, Navon & Norman, 1983; Paquet & Merikle 1984, 1988; Pomerantz, 1983; Ward, 1982). As Ward (1983) proposed some of the controversy surrounding the issue of global precedence originates from using the same vocabulary to refer to different processes. Meanwhile, and more importantly the

controversy originates from generalising empirical findings to the theoretical level. The global/local precedence hypothesis has usually served as a concept to explain the empirical findings regarding the faster response time to any of the global or local levels (Boer & Keuss, 1982; Navon, 1977); or the asymmetric interference of the identity of one of the two levels on processing of the other level (e.g., Hoffman, 1980; Miller, 1981; Pomerantz, 1983).

Perhaps the simplest definition of the global precedence hypothesis is that the processing of the global configuration is accomplished before the processing of local components (Navon, 1991). Paquet and Merikle (1988) defined global precedence as the priority of global configuration in perceptual processing. Since this definition was too general, they provided the example of Navon's (1977) study to clarify the meaning they had in mind from the term "priority." From that example they concluded that the global configuration is identified more rapidly and is ignored with more difficulty than the local component. Wandmacher and Arend (1985) used the concept of global superiority to refer to the faster discrimination, classification, and matching of a global feature in comparison to a local element. Temporal precedence, however, is one possible aspect of the dominance of either the global or local levels. A certain property of a visual object which is responded to faster or more accurately might interfere with the processing of the other properties which are processed later. Also a property might be more resistant to the interference of the other properties, might be more resistant to degradation, or it might be easily identifiable under shorter exposure time than the other properties. In all the above mentioned conditions it can be suggested that, the processing of that property preceded the processing of the other one (Ward, 1983). From among all possible experimental results which may be referred to the global/local hypothesis, speed of reaction time and the interference of the content of either the global/local level is more commonly considered as global/local precedence.

Navon (1977) found that, in a Stroop-type task, conflicting information between the global and local levels had an inhibitory influence on responding to the local components, but not on responding to the global configuration. This finding was interpreted as a major

criterion of the global precedence effect and as the sign of its inevitability. This effect was called asymmetric interference in the literature. For example, Hughes, Fendrich, and Reuter-Lorenz (1990) suggested that the global structure interferes with the processing of local patterns more than the interference produced by the local structure on the processing of the global configuration. The asymmetric effects of the consistency or inconsistency of the identities of the two levels were interpreted (e.g., Navon, 1977; Pomerantz, 1983, 1989; Pomerantz & Kubovy, 1981; Pomerantz & Sager, 1975) as an indication of the earlier availability of the global information. According to this view the level which is available earlier will interfere with the processing of the other level. Hughes, Fendrich and Reuter-Lorenz (1990), however, argued that the asymmetric interference can occur even when response times to the global and local levels are equal.

Most of the disagreement surrounding the global precedence paradigm may be resolved if researchers employ uniform vocabulary. To avoid confusion throughout the present research the term global/local precedence is used as the theoretical description of wholistic/analytic processing. On the other hand, the concepts global/local advantage, and global/local interference are used to refer to the empirical findings obtained in various studies (LaGasse, 1993). Thus, global advantage refers to the faster processing of the information at the global level, and global interference indicates that the facilitation or interference caused by the global level on the local level, when two levels are consistent or inconsistent with each other, is more than the facilitation and interference caused by the local components on the global configuration. In the next section some attention will be given to main performance measures used in the global precedence hypothesis.

2.2 Global/Local Precedence and Performance Measures

Most psychologists are inclined to consider as primary those properties which are processed under a speed stress condition (Garner, 1978b). Properties which are responded to faster are assumed to be processed first. In experiments concerning the global/local precedence hypothesis relative speed of identification of global and local

levels is used as a method to infer global/local precedence. Another method is by evaluating the absence or presence of differential performance produced by the response irrelevant properties. That is if the relevant/irrelevant properties of one level affect the accuracy or speed of processing of the other level, it has been argued that the underlying processing is sequential at some level or it is parallel but at different rates.

The relative speed of identification and interference are used in different ways to measure the theoretical issue of the precedence of the global/local levels. Following are examples of the methods employed by some workers: (a) Kinchla (1977) studied global precedence effect by changing the degree of redundancy of the global and local levels. They presented global stimuli composed of different local components (Figure 2) for 10 msec on each trial. The task was to detect a target letter at the local level. The probability of the occurrence of the target letter in one of the two large letters was twice that of the other. The results of this study indicated that the global level was processed prior to the local level, even with the global property which was not structurally contained by the stimulus.

Figure 2. Stimuli used in Kinchla's (1977) experiment.

(b) Lasaga (1989) reported another measure. The detracting of attention from local components by good global configurations was evaluated as a measure of global/local precedence. A cued-location method was employed. A stimulus matrix was presented for a duration which maintained a pre-specified accuracy level. The stimuli were composed of two coloured letters arranged vertically, horizontally, and obliquely. It was suggested that oblique images were detected slower than the horizontal or vertical ones. Therefore, it

was suggested that local conjunctions of colour and form would be more accurate in the vertical/horizontal global patterns than in oblique patterns. The findings of this study suggested that good global properties are more salient than bad ones in changing the direction of attention from the local units.

(c) In another study Sebrechts and Fragala (1985) examined the effect of changing the goodness of the pattern in the global or local level in the response-irrelevant level on performance to the other level. In fact, in this method precedence of processing was measured by the effect of the goodness of an unattended level on RTs to the attended figure.

(d) Given that it is difficult to produce independent variations in the stimulus structure at different levels of complexities, Lasaga (1989) suggested an alternative method to examine performance with information of various levels of complexity. In this method subjects were required to classify the stimuli into groups according to different rules. Patterns of performance with stimulus sets of successively greater complexity were compared with each other. The performance with each simple property was determined, then these properties were combined to form more complex stimuli. The patterns of responses were successively compared with the previous ones. The underlying assumption of this procedure is that if a property of lower level complexity contributes to the performance, that level will affect the relative speed of performance in the same way as it is displayed individually.

It was also speculated that if global/local precedence is sequential, the discrimination between stimuli that share a property at the level of precedence would be more difficult than the discrimination between stimuli which do not share a property at that level. However, if the global and local levels are processed in parallel, similarity of units in both levels will affect performance. Meanwhile, discrimination of stimuli which do not share any property at any level will be easier than tasks that involve discrimination between the most discriminable properties, which, in turn, will be easier than a discrimination when there are less discriminable properties. The results of Lasaga's (1989) study demonstrated that stimuli with equally recognisable components that have

global properties in common discriminated slower than those which do not share those global properties. In the latter condition a classification based on global properties was faster than a classification according to component properties. From these results Lasaga concluded that processing of global properties precedes the processing of local properties.

(e) The global precedence has also been measured by the analysis of confusion matrices. In this method it is assumed that briefly flashed letters and letter-like symbols are confused with each other when they are similar in global configuration, defined by contour similarity than the condition in they were similar in local component (Lupker, 1979).

(f) Lasaga and Garner (1983) found that two oblique lines are more confusable than two horizontal or vertical lines. However, the results of an experiment reported by Lasaga (1989) using four right angle stimuli (Figure 3) indicated that the discrimination between angles that were made up of oblique lines was easier than discrimination between angles composed of vertical and horizontal lines. These stimuli had properties at two levels of complexity: orientation of lines at local level, and the direction of pointing of the whole figure (i.e., corner versus arrow configuration). The pattern of results in a classification task was not compatible with the results of the study of Lasaga and Garner (1983). Based on these results any precedence of local information was ruled out. Lasaga assumed that if the processing of the global and local levels in Figure 3 is parallel, the easiest discrimination task should be the discrimination between angles which do not share any property at the global and local levels (i.e., up-arrow vs. down-corner and down-arrow vs. up-corner). These may be followed by discrimination of stimuli that share properties at only one level or two levels. However, the obtained pattern of results was not compatible with this assumption. Therefore, Lasaga (1989) argued that if the processing was serial, the task which involves discrimination between stimuli that do not share a property at the global level would be easier than the task which requires sharing a property at that level, even if the latter stimuli did not share a property at the local level. The finding that the (Up-corner)(Down-corner) task was harder than (Up-arrow)(Down-arrow) task weakly suggested that sequential processing occurred in that study. The

results of this experiment indicated that the highest level of complexity was not the sum of the complexities of lower level components.

Figure 3. The stimulus set reported in Lasaga's (1989) study.

From left-to-right: U-arrow (up arrow), D-arrow (down arrow), U-corner (upper corner), and L-corner (lower corner).

From various performance measures mentioned above, and others that are not outlined in the present research, global/local advantage and asymmetric interference are the measures most extensively used in the literature. Because of the complexity of the mechanisms involved in the latter measure in continuation of the present study it is appropriate to be explained in more detail. However, before that I will start with a brief introduction of the Stroop and Garner effects which have been used as two main interference measures in the literature. Garner interference is not experimentally investigated in this thesis but is discussed as an issue which requires further investigation.

2.2.1 Stroop-Type Interference

Stroop effect shows a very fundamental aspect of attention: some features are ignored easier than others (Mewhort, Braun, & Heathcote, 1991). A Stroop task provides a clear illustration of individuals' capacity to attend selectively and to control their attention. The task is to attend to only one dimension of a stimulus with two different dimensions. In the classic form subjects are shown words printed in same- or different-coloured ink. The task is either the recognition of the written word or naming the ink colour. When the task is to read the word, the ink colour has no effect on reading time. When the task is naming the colour, ignoring the effect of word form is quite difficult. The Stroop effect also may be interpreted as the relative difference in the speed of

processing of colour naming and word reading. It may be assumed that word reading arrives at the response stage of processing before colour naming. Therefore, the word reading interferes with colour naming. In another study Glaser and Glaser (1982) manipulated the stimulus onset asynchrony (SOA) of a colour patch and a colour word, and did not find any interference of colour patch on word reading when presentation of colour preceded the word. From this result they concluded that the interference did not originate from the difference in the speed of processing of the colour naming and word reading. Otherwise, earlier presentation of a colour patch would produce an interference effect in favour of the colour naming dimension. If Stroop-type interference does not originate from the difference in speeds of processing to the colour patch and colour name, what might be the possible source of Stroop effect?

Posner and Snyder's (1975) interpretation of the Stroop effect seems to be logical. They suggested that the difference in the reaction times to the word reading and colour naming task is because of the difference between automatic and controlled processing which is associated with word reading and colour naming, respectively. In other words, the word reading interferes with colour naming because the former is automatic and it is processed faster than the other one which is a controlled and slow process. It appears that performance in a Stroop-type task lies along a continuum (Shiffrin & Schneider, 1977). The reaction time to any of the levels depends on the degree of automaticity of each task which is established by practice. Cohen, Dunbar, & McClelland (1990) simulated a computational model of the performance in a Stroop task, simulating the time course of processing and the effect of learning. The model was compatible with the experimental data. In this study, subjects practiced naming some shapes presented in white for 20 days. Shapes were named as colour names. Therefore, an artificial association was made between these shapes and colour names. After 1, 5, and 20 days of practice, subjects were tested with neutral, conflicting, and congruent stimuli in both shape-naming and colour-naming. The results indicated a change in the direction of timing advantage and interference by practice. From these data MacLeod & Dunbar concluded that the attribute of automaticity is not a stationary or constant process.

Interference effects such as Stroop and Garner which are suggested to have wholly mandatory origins, may contain large optional components (See, Melara, Marks, & Lesko, 1992). It seems that speed of processing and interference effects are affected by the amount of training a subject receives (Dunbar & MacLeod, 1984; MacLeod & Dunbar, 1988). Automaticity may be defined by lack of requirement for attention. However, it seems that even in the most automatic task, some degree of attention is required (Kahneman & Treisman, 1984). The degree of automaticity and control of attention depend on task requirements and the amount of previous practice on any of the levels. Therefore, it is possible to change the relative speed of processing of levels in a Stroop-type task, by practice.

Stroop-type relationship between the global and local levels of compound patterns results in a pattern of response which is called Stroop-type interference. This type of asymmetric interference refers to a condition in which reaction times to the attended global or local level are unequally interfered with or facilitated by the congruent or incongruent identity of the unattended level. It is also suggested that similar to the Stroop-type task global and local levels are processed by different channels.

The interference may operate differently with the compound patterns of different relationship. The result of a study by Wandmacher and Arend (1985) with the stimuli illustrated in Figure 4, indicated only a negligible Stroop-type interference by both irrelevant global and local levels. Wandmacher & Arend suggested that the global advantage effect is not associated with Stroop-type interference in type-N stimulus. In fact, task requirements determine the process of the selection and utilisation of a global configuration for a response. Thus, the global/local interference depends on "the relevance of the global features which is defined by the task (Wandmacher & Arend, 1985, p.156)." From the literature mentioned above on the Stroop-type interference it may be concluded that the extent of interference of a property on the other depends on the type of compound pattern.

As Glaser and Glaser's suggested, it seems that Stroop-type interference does not originate from the difference in the speed of processing of the two levels. It also appears

that the difference in reaction times in a Stroop-type task originates from the difference between automatic and controlled processes (Posner & Snyder, 1975). If this argument is true and if the analogy made between the original Stroop-type tasks and the inconsistency between the global and local levels of a compound pattern is reasonable, it can be suggested that the magnitude of Stroop-type interference in the processing of the global and local levels depends on the extent of subjects previous familiarity with either of the two levels. Meanwhile, it might be argued that the pattern of interference varies according to the type of relationship between the global and local levels. For example, in a

Figure 4. Stimuli used in Wandmacher and Arend's (1985) study.

compound pattern with featural relationship if the global configuration is something which subjects have previous relationship with, the global configuration might produce more Stroop-type interference on the local level than the vice versa. On the other hand, when the subject's previous familiarity with their global and local levels is the same, such as compound patterns with placeholder relationships, Stroop type interference might be less distinct than the other types. Meanwhile, it seems possible to change Stroop-type interference by training. In the experimental chapters of this thesis the Stroop-type

interference will be studied using compound patterns of inclusion and placeholder relationship.

This section will be followed by a short introduction to Garner-type interference. Garner interference will not be studied experimentally in this thesis, but it is important because the existing literature has provided contradictory results between these two types of interference. This is an issue which requires further investigation.

2.2.2 Garner-Type Interference

In a Stroop type task, subjects respond to the relevant structural component of a stimulus while trying to ignore an irrelevant component which is assigned to an incompatible response. In Garner type task, subjects try to ignore an irrelevant component that varies unpredictably from trial to trial. Therefore, Stroop interference is probably caused by the content of an irrelevant component, while Garner interference seems to be caused with variation in the irrelevant component across trials (Pomerantz, Pristach, & Carson, 1989). To study Stroop and Garner interferences independently, Pomerantz (1983) conducted 5 experiments in 9 experimental conditions outlined below. In the first 4 experiments the stimulus was a compound letter of either an E or an H made up of either Es or Hs, resulting in four different combinations (Figure 5).

<u>Global</u>	<u>Local Dimension</u>	
<u>Dimension</u>	<i>Level L1</i>	<i>Level L2</i>
<i>Level G1</i>	L1G1	L2G1
<i>Level G2</i>	L1G2	L2G2

Figure 5. The logical structure of the stimulus set used by Pomerantz (1983).

1. Local control A. The task was discrimination of L1G1 from L2G1. In fact, this condition measured the discriminability of the two levels of the local dimension when global configurations were constant.

2. Local control B. Subjects were required to discriminate L1G2 from L2G2. Similar to condition 1, the discriminability of the two levels of the local dimension was measured while the global level was held constant at the other level.

3. Global control A. The task was the discrimination of L1G1 from L1G2. That is the discriminability of the two levels of the global dimension was measured while the two levels of the local dimension were the same.

4. Global control B. The task required discriminating L2G1 from L2G2. It was identical to the above condition except that the local dimension was held constant.

5. Positive correlation. The task was discriminating L1G1 from L2G2. The two stimuli differed in both local and global dimensions. The subject was free to discriminate them on the bases of either dimension. This task assessed the degree to which information can be extracted from both dimensions simultaneously.

6. Negative correlation. The task was discrimination on L1G2 from L2G1. Similar to the positive correlation condition, the two stimuli differed in both dimensions, but dimensions in the latter condition were paired in the opposite fashion so that both stimuli are of the Stroop variety.

7. Filter at local. All four stimuli appeared. L1G1 and L1G2 stimuli were assigned to one response button while L2G1 and L2G2 were allocated to the other. Therefore, similar to conditions 1 and 2, the local dimension was the target level (relevant), but the global dimension varied orthogonally to the local one and should be ignored for correct response. In this condition two stimuli were congruent (the identities of the two dimensions were the same) and two stimuli were incongruent (the identities of the two dimensions were inconsistent). According to Pomerantz, slower reaction times in this condition and the next condition indicated a failure of 'selective attention' to the relevant dimension.

8. Filter at global. L1G1 and L2G1 stimuli were assigned to one response key, while stimuli L1G2 and L2G2 were assigned to the other. Apparently, the relevant (target) dimension was global and the local dimension must be filtered.

9. Condensation. Stimuli L1G1 and L2G2 stimuli were allocated to one response Key, while L1G2 and L2G1 were assigned to the other. Since both dimensions are relevant to this task none of them can be ignored. Subjects were free to respond in any fashion desired.

The most important aspect of the results of Pomerantz's (1983) first 4 experiments was that Stroop and Garner asymmetries may occur in opposite directions. One possible interpretation of this finding is that these two interferences do not measure the same thing. It appears that Garner interference and Stroop interference are produced at different levels of perceptual processing. Pomerantz suggested that Garner effect occur at a perceptual level and Stroop effect at postperceptual, response level. Using the example of the original Stroop effect, although a conflicting colour word impairs one's ability to name that ink colour it does not seem to affect one's perception of the ink colour. In contrast, Garner interference appears to involve perceptual aspects. Therefore, it seems reasonable to conclude that Garner interference measures sensitivity to the variation of relevant dimension but not to its specific content.

Pomerantz's Experiment 5 was conducted using what he called Type-N stimulus (Figure 4). The results of this experiment demonstrated no trace of Garner interference by both global and local levels in either RTs or error rates. From the assumption that the local and global dimensions of these patterns were separable (Garner & Felefoldy, 1970) Pomerantz concluded that with separable dimensions perfect filtering of dimensions is possible. Therefore, by definition separable dimensions show neither local nor global Garner interference. Pomerantz's (1983) study indicated that the global level in some conditions may be perceived prior to local components, but when subjects directed their attention toward local components, they are perceived without the influence of the global configuration to which they belong. In summary Pomerantz's (1983) study revealed that there are some circumstances under which global/local Garner and Stroop interferences

may arise. However, the necessary and sufficient conditions for these circumstances remained unclear. Coming back to the main line of research, in the next section I will discuss whether global/local advantage and interference co-vary.

2.2.3 Temporal Advantage and Global/Local Interference

As was mentioned, the original proposal of the global precedence hypothesis used the global advantage and Stroop-type interference as the performance measures to demonstrate the global precedence effect. It was originally assumed that these two measures reflect the same perceptual mechanism (Navon, 1977, 1981a). However, later studies (e.g., Lamb & Robertson, 1988; Lamb, Robertson, & Knight, 1989; Lovegrove & Pepper, 1994; Robertson & Lamb, 1991; Zhou, May, & Williams in press) have suggested that global/local advantage is independent from global/local interference, and they may be mediated by different perceptual mechanisms. Navon and Norman (1983) suggested a two stage model of global precedence. The global/local advantage originates from the first and global/local asymmetry from the second stage. Neurophysiological data has also suggested that separate cortical mechanisms are probably involved with the global advantage and asymmetric interference (Lamb & Robertson, 1988, 1989). For example, it is reported that unilateral temporal lobe lesions can eliminate interference effects while keeping RT advantage intact (Lamb & Robertson, 1989). Therefore, global/local interference does not simply reflect the order or the relative speed of processing of the global and local levels.

Robertson and Lamb (1991) also proposed that global interference is not related to global temporal advantage in both normal individuals and patients with lesions to the right or left hemisphere. Meanwhile, despite the original global precedence hypothesis, the local level may temporally precede the other level. Therefore, some workers (e.g., Pomerantz, 1983; Robertson & Lamb, 1991) have considered global/local interference as the main measure of the global/local precedence effect. For these workers even in a condition where the global level is processed slower than the local level, global interference should be considered an indicator of the global precedence effect.

Patterns of global/local interference and global/local advantage may change according to the type of compound patterns. One of the thrusts of this thesis is to study these two effects using compound patterns of placeholder and inclusion relationship and to test their possible co-variation or dissociation. This will be one of the major concerns of Chapters 3, 5, and 6. However, in continuation of this section I will provide a brief explanation of an issue which is of major importance to the global/local precedence hypothesis, the problem of whether the possible precedence of either global or local level is stationary or changes throughout global/local precedence. This aspect will not be manipulated experimentally, but I will provide some speculations about it in the Conclusion Chapter.

2.2.4 Stationary and Queue Hypothesis

A problem with the global/local precedence hypothesis concerns whether the information of one of the levels is more active throughout processing. Navon proposed two possibilities with regard to this problem. One possibility is that there is a shift in the dominance of the global precedence effect. An initial global dominance is later superseded by a local dominance. Navon (1991) called this the 'queue hypothesis'. The other possibility is that the global information is more available or active than the local information at all stages. Navon referred to this as 'stationary hypothesis'. The queue hypothesis is different from the temporal precedence hypothesis. According to the latter concept the availability of the global level does not decline during the processing of local level. However, the queue hypothesis implies the modulation of global information over time. There may be at least two experimental designs to test if the global advantage is stationary. One is to examine the relative availability of global and local features at some time after the exposure of the stimulus. This plan requires the use of a Stroop-type (1935) interference task. The other is to use a design similar to the design Navon (1977) applied. In that experiment the name of a letter was presented auditorially while the subjects viewed a compound stimulus which could be consistent, inconsistent, or neutral with it. Navon (1991) used a paradigm similar to that experimental design. The idea behind this

paradigm was that if the queue hypothesis was correct, variation in the time interval between the auditory and the visual stimuli would have some effect on the measure of global advantage. To control the effect of a bias which may act in favour of the global level, Navon (1991) used spatial uncertainty with a very small range about a quarter of the width of a global shape to the right or to the left. The results of that experiment indicated that global information is more active than local information in all stages of processing. This data was in harmony with stationary hypothesis.

2.3 A Short History of the Controversy in the Literature

The present review chapter will be continued by a report on the controversy in the literature. Not all studies on the processing of the global and local levels of compound patterns have shown global advantage and interference. The report of the existing controversy may indicate the possible role of factors which this controversy may originate from it.

2.3.1 Global Advantage and Interference

'The global precedence' hypothesis initially was outlined as a model in which different levels of the stimulus were encoded in parallel, with the first dimension encoded entered into a serial comparison process in short-term memory. According to this approach the global form is inevitably the first to be encoded. Navon (1977) reported both global advantage and interference. Three types of stimuli were used in his study: (1) large letters made up of small identical letters which were consistent or inconsistent with the global figures, (2) large letters made up of small non-letters, or (3) large non-letters made up of small identical letters. In his first two experiments the task was to respond to an auditorially presented name of a letter while looking at a large letter made up of small letters. Results showed that subjects' responses to the auditory stimuli were interfered with by the global level, but not by the local components. Local components were also identified slower than the global configurations. From these results Navon concluded that

the response to an auditorially presented name of a letter was more prone to interference by the global configuration of a compound pattern than by the local level. This pattern of results was called 'global precedence'. Similar findings have been reported by other workers (e.g., Badcock, Whitworth, Badcock, & Lovegrove, 1990; Hughes, 1986; Lamb & Robertson, 1990; Lamb & Yund, 1993; Navon, 1991; Ward, 1982, 1983).

Using type-N stimuli (Figure 4) similar to ones employed by Pomerantz (1983, Experiment 5), Wandmacher and Arend (1985) argued, based on the manipulation of exposure times, that the global features are not extracted earlier than the local features. Wandmacher and Arend did not generalise their results to conclude that local features are necessarily processed faster than the global configuration. However, they questioned the generalisability of the global temporal advantage. The main point of Wandmacher and Arend's suggestion was that the global precedence can occur even if the global features were extracted slower than the local ones.

2.3.2 Local Advantage and Interference

Pomerantz and Sager (1975) in one of the earliest studies on asymmetric influence of the global configuration on local components showed that the processing of local components preceded the global configurations. Speeded classification task was used in this study. The stimuli were patterns made up of spatial arrangement of the letters X, Y, V, and O (Figure 6). Three lines of explanation may account for asymmetric interference between the global and local levels of stimuli. First, asymmetry may be explained as the result of the fact that the global and local levels are processed by different perceptual mechanisms. Second, asymmetry may arise when different modes or hierarchically related levels of processing are required for the two dimensions. The third line of explanation is based on the logical physical relationship between dimensions without appeal to indirect inferences about modes of processing. The latter approach which was supported by Pomerantz and Sager (1975) shares elements with the Structuralists' view. Based on the results of this study Pomerantz and Sager suggested that the global and local levels of stimuli used in their study were integral. Therefore, when dimensions were

combined orthogonally and redundantly, gains emerged in favour of local components. In fact, although interference effects were found in both directions, their magnitude was larger in favour of local components. Pomerantz and Sager (1975) suggested that the interference was not due to the difference in discriminabilities of the levels. In contrast it was explained in terms of attentional strategies. To explain the role of attention on local interference, they proposed a model based on attentional strategies. According to this model, when local is the relevant level, the subjects allocate their attention to a single location common to both configurations because only one element needs to be attended for a correct response. This strategy seems to slow down the processing of configural information and decreases its interfering effect on the processing of the local level.

Figure 6. The six stimulus sets used in Pomerantz and Sager's study (Pomerantz & Sager, 1975).

There are some other reports on the priority of the processing of the local components on the global configuration. For example, studies on perspective perception

(e.g., Attneave, 1971; Rock, 1975; von Grünau, Wiggin, & Reed, 1984) have suggested that perspective orientation is not a global process. In fact, it consists of multiple local processes with a limited spatial extent which increases with eccentricity. The spatial characteristics of these processes seem to have their origin in early visual processing, but later they are integrated more globally. Some other studies have reported a reversal in global/local processing according to variations in factors such as size of the stimulus. In the next section some of these studies will be explained.

2.3.3 Reversal in Global/Local Advantage and Interference

Not all the studies in the 'global precedence' hypothesis reported a global advantage and interference. The results of an experiment conducted by Hoffman (1980) indicated that in a 'focused attention' condition subjects were unable to fully attend to a required level, and reaction times were faster when the local and global levels were consistent in comparison to the condition in which they were inconsistent. The amount of interference, however, produced by any of the levels of the compound pattern on the other were equal. From these results Hoffman (1980) concluded that earlier processing of the global level is determined by the attention a subject allocates to the global level and the psychophysical quality of the forms. The manipulation of the quality of information in Hoffman's study (Experiment 2) indicated that the interference of any of the levels on the other depended on the relative visibility or 'quality' of the level. This suggestion does not seem to be incompatible with what was suggested in the previous chapter about the role of automatic and controlled responses in the Stroop-type task. It appears reasonable to conclude that more visible stimuli or stimuli with better quality are processed through more automatic channels than less visible stimuli.

Kinchla and Wolfe (1979) studied the differential effect of angular size of compound patterns on the global and local processing, using a placeholder type of stimuli. The results of this experiment showed a global advantage only when the visual angle size of the compound pattern was smaller than 6° to 9°. They suggest that there is an optimum stimulus size (about 6° to 9°) for speed of processing. From these results

Kinchla and Wolfe concluded that Navon's conclusion about the inevitability of global processing was not correct.

Kinchla and Wolfe's findings were replicated in series of studies conducted by Lamb and Robertson (1988, 1990). However, the latter workers suggested that the speed of processing of the global level is overtaken by the local level not at a fixed visual angle size, as proposed by Kinchla and Wolfe. Rather they found an indication that the attentional window adjusts itself to an optimum size depending on the disposition of the stimulus set. Studies by Kinchla and Wolfe (1979) and Lamb and Robertson (1988, 1990) indicate not only the importance of the role of size of the compound pattern in the processing of the global and local levels, but also the possible role of eccentricity of the global and local levels on the processing of the two levels. The local advantage of large stimuli in the above mentioned experiments may result from the faster reaction times to the local components projected to the most foveal locations in comparison to the global configuration projected to the peripheral locations.

The global/local advantage and interference effects seem to be influenced by the type of the compound pattern. Factors such as number and size of the local components, continuity or discontinuity of the form have been reported to play an important role in the processing of the two levels. For example, using a classification task, Kimchi and Palmer (1985) indicated that the global and local levels of few-element patterns are perceptually integral. Large rectangles or squares composed of either rectangles or squares were used in that study (Figure 7). The results demonstrated that RTs to the local components were not affected by dimensional instructions. That means there was not a significant difference between RTs to the local level when they were classified according to being rectangle or square, and checker board or grating. The integrality of the global configuration and local elements demonstrated that few element patterns are processed in terms of a form accompanied by figural parts. However, levels of the many-element stimuli were processed in terms of forms and texture. That is global and local levels were not treated perceptually the same in the many-element and few-element patterns. From these findings, Kimchi and Palmer (1985) suggested that since global configurations of many-

element patterns interact differently with a texture and with a local form, it is necessary to specify which aspects of the global and local levels are considered when testing a global advantage effect. Because of the difficulty in specifying whether the local level is processed as a texture or a form, Kimchi and Palmer (1985) proposed that processing

Figure 7. The four sets of compound patterns used in Kimchi and Palmer's (1985) study.

of neither global configuration nor the local components of the many-element patterns is prior to the other. Meanwhile the interference effect between them seems to be mutual. Therefore according to these workers, few-element patterns seem to be better candidates for testing this hypothesis.

In summary it does not seem appropriate to generalise the so called 'global precedence effect'. The variety of factors such as the type of stimulus, the density of components in the form, length to width ratio, continuity of contours, clarity (distorted versus. undistorted forms), retinal location, and many other factors affecting speed of processing of any of the structural levels and their interference on each other casts serious doubt on the generalisability of these effects. In the present thesis the effects of three main groups of factors affecting global/local precedence will be investigated experimentally: The effect of discriminability, with specific reference to the effects of size and eccentricity; the effect of stimulus type based on the classification suggested by the writer of this thesis in Chapter 1; and role of postperceptual factors, such as attention and size/eccentricity uncertainty. Section 2.3 is an introduction to a critical review of the literature on factors affecting 'global/local precedence'.

2.4 Factors Affecting the Global/Local Advantage and Interference

2.4.1 Attention

The 'global precedence effect' implies that the global configuration interferes with the processing of the local component. However, this interference does not necessarily mean that global precedence results from faster availability of information. For example, Miller (1981) suggested that local and global information is available to decision processing with a time course similar to each other. Therefore, the difference in the processing of the global and local levels may result from the differential ease of directing attention to one of the levels.

Navon's (1977) initial view of the global precedence hypothesis was in terms of attentional factors, when he proposed that "since local features often served as

constituents in more global structures, the identification of the global features is a very useful device for narrowing down the range of candidates for accounting for a certain local region" (Navon, 1977, p. 356). Several experiments have indicated that attentional manipulation can affect global advantage and interference (e.g., Ward, 1982). Ward showed that RT was faster for a given level if the same level was just been responded to. Ward termed this the level-readiness effect, referring to faster reaction time to a target if it was embedded at the same target level as the target level of the trial just processed.

Two main attention strategies which have been referred in studies of the global precedence effect are 'divided attention' (i.e., a condition in which both levels are relevant) and 'selective or focused attention' (i.e., a condition in which subjects have to respond just to one level while trying to ignore the irrelevant level) conditions. Navon and Norman (1983) did not report any significant change in RT resulting from 'focused and divided attention' allocation strategies. However, the comparison of reaction times in 'divided and selective attention' conditions of that study and several other experiments indicates that blocked presentation condition ('selective attention') facilitated performance almost equally to the global and local levels (Alwitt, 1981; Bashinski & Bachrach, 1981; Hoffman, 1980; Hughes, Fendrich, & Reuter-Lorenz, 1984; Kimchi, 1992; Navon & Norman, 1983).

It seems that response times to both the global and local levels are faster in a blocked ('selective attention') than a randomised ('divided attention') presentation condition. Meanwhile it is assumed that randomised presentation favours processing of the global level more than the local. Therefore if global advantage is found in a randomised condition, it might be interpreted as the involvement of postperceptual factors. In contrast when patterns of responses to the global and local levels are indifferent to the global and local levels in the two presentation conditions, it may be suggested that attentional factors are not involved in forming these patterns. In the experimental chapters of this thesis the pattern of responses to the global and local levels will be studied in randomised and blocked presentation conditions.

2.4.2 Shape Goodness

Configuration, homogeneity, and similarity in the structure of a pattern influence its perceptual organisation. The perceptual organisation of a display in return affects the speed of identification and accuracy rate to that stimulus. The identification of a target located within a good form is poorer than the one is not part of a good shape (Banks & Prinzmetal, 1976). Increasing the level of noise results in the perceptual grouping of the noise elements, and improves the performance for the global configuration. Previous familiarity with a stimulus is also closely linked with the perceived goodness of that pattern. Previous familiarity is suggested to generate some kind of prototypes and transformation of previous experiences which may facilitate global precedence in contrast to local precedence (Regan, 1981; Treisman, 1986). Familiarity seems to be very useful whenever categories are complex, ill defined, or are not learned completely. It seems reasonable to speculate that subjects respond faster to either global or local level which is more familiar than and has a better shape than the other level.

Although goodness of a form and the facilitation which it provides for information processing is a concept which is close to the basic organising principles of Gestalt psychology (LaGasse, 1993), Gestalt psychologists did not provide a clear definition of it. For example, Koffka (1935/1963) suggested that goodness of a shape depends on the prevailing conditions. A concept close to the term goodness in Gestalt psychology is good continuation. It is an important factor in the perception of hidden figures (Pomerantz & Kubovy, 1986). It can easily override the law of closure and symmetry. A good structure according to Gestalt, is one which possesses only a few simple properties, arranged in a symmetrical fashion. On the other hand, poor patterns are assumed to have complex structures. Garner (1970) stated that good patterns have few alternatives. This rule may be applied to some stimuli, but it does not seem to be valid to the reflection and rotation subsets (Pomerantz, 1981).

Lasaga (1989) reported that good global properties are more salient than bad global properties. According to this definition goodness of either global or local level interferes with the processing of the other level and delays its perceptibility. In Lasaga's study a

stimulus matrix of two colour letters forming a vertical, horizontal, or oblique line was displayed. The duration of the stimuli was maintained in a level to provide a pre-specified accuracy rate, followed by a brief mask, and then a cue to indicate the location of the local element. Although previous studies (e.g., Lasaga & Garner, 1983) had indicated that vertical and horizontal stimuli were processed faster than oblique stimuli, Lasaga (1989) reported that items located along vertical and horizontal lines were less correctly conjoined than items along oblique configurations. Therefore, she reported that good global configurations detract attention from their local components. In another study, Sebrechts and Fragala (1985) found that in a same-different paradigm goodness of the unattended level interfered with the perception of the other level. Their results suggested that a good pattern at either the global or local level detracts attention from the other level.

Goodness as an Attentional Factor: Ward provided an explanation of global advantage which was very similar to shape goodness interpretation. Consistent with Treisman's (1982) explanation he suggested that all the features of a form are processed in parallel, with approximately the same processing time and without the need for focal attention. Then, these separately extracted features conjoin into a perceptual view by allocation of attention to a particular spatial location. This means that the arbitrary conjunction of features is a serial process. Ward suggested that the global precedence effect is at the level of conjoining features into a visual object. This model demonstrated that more conspicuous features are processed faster than less good or less conspicuous features. Ward's model provides a good explanation of why foveal (Pomerantz, 1983), conspicuous (Ward, 1982), and optimum size (Kinchla & Wolfe, 1979) features can be responded to faster than peripheral, inconspicuous, and non-optimum size ones.

Goodness and Spatial Frequency: Low and high spatial frequency channels have been suggested as the possible carriers of the global and local information (Badcock, Whitworth, Badcock, & Lovegrove, 1990; Kinchla & Wolfe, 1979; Navon, 1977; Weisstein, Maguire, & Brannan, 1992). LaGasse (1993) conducted a series of

experiments in a similarity-difference judgment task with many- and few-element stimuli to study the relation between shape goodness, spatial frequency, and the global/local advantage effect. The results of this study indicated that subjects rated a reduction in number of elements of a compound pattern as an indication of goodness of a pattern. Global advantage was obtained for many-element patterns, suggesting that global precedence originates from processing bias to the global configuration in comparison to local components. From these results LaGasse (1993) concluded that global advantage depends on the quality of the global form (goodness) and postperceptual processes. LaGasse proposed that global and local information was encoded and available at the same pattern of time. An increase in the sparsity was associated with an observed global advantage in large patterns but not in small patterns. LaGasse's interpretation of these results was that small figures may not be appropriate stimuli for the study of sparsity effect on the global precedence hypothesis. LaGasse's second experiment showed that shape goodness improved the performance in an identification task. Global advantage was found for many-element stimuli and not few element ones. Generally the results of this study showed that global advantage appears to depend on the goodness of the global configuration, and goodness of the global configuration is mediated by low spatial frequency channels.

Distortion and the Quality of Contours: Hoffman (1980) manipulated the quality of information contained in a compound pattern by distorting either the global or local level. The results of this experiment showed that either the local or global advantage and/or interference can be obtained depending on which level was distorted. The comparisons between RTs in a similarity/difference task (Navon, 1983) indicated that judgments on similarity/difference of patterns with serrate edges were slower than those with smooth edges. Moreover, the advantage of smooth-edged patterns was stronger in triangular patterns than rectangular ones.

Generally goodness of a pattern seems to be an important factor in the processing of the global and local levels of a compound pattern. It depends on a number of factors such

as previous familiarity, continuity of contours, width-length ratio, quality of the contours, number of elements, and spacing among components. Shape goodness also facilitates allocation of attention to that level of a compound pattern which has better shape than the other. Density/Sparsity and number of elements of local components, as factors affecting shape goodness, will be studied independently in the next sections.

2.4.3 Density/Sparsity

Density/sparsity of a display, i.e., the spacing of local components of a compound pattern, affects the processing of the global/local levels (Lovegrove & Pepper, 1994; Martin, 1979a). Martin (1979a) reported a global advantage in the dense, and a local advantage in the sparse conditions. It was also reported that an increase in the density of the local components facilitates the perception of the global form (Lovegrove & Pepper, 1994). The global configuration may suffer from codability with decreasing the number of the local elements or their sparsity. However, Navon (1983) proposed that a decrease in the global advantage is not always accompanied by an increase in sparsity. Navon studied the relative availabilities of global and local levels using geometric figures in a 'same/different' judgment task. Pairs of geometric figures were used as stimuli. Global advantage was obtained by triangular patterns, was attributed to the difference in size of the levels. With rectangular sparse patterns, although the global level was identified faster than local components, no effects of size, number of elements, and spacing were obtained. From these results, Navon (1983) concluded that the availability of global or local properties is not always affected by sparsity. Meanwhile, the extent of the effect of sparsity depends on the type of the stimulus (i.e., triangle versus rectangle in that study). Large difference in sizes of the global and local levels of the stimulus in Navon's (1983) study was criticised by LaGasse (1993). LaGasse argued that insensitivity of the global advantage to an increase in sparsity in Navon's (1983) study was possibly resulted from the low discriminability of local components in that study. In other words, local components were so small that their visibility was not improved in the sparse condition.

Density/sparsity of a stimulus seems to be directly dependent on the number of local elements in the similarity judgment and classification tasks. Klein and Barresi (1985) studied the effect of variation in the number and spacing of elements on the proportional enlargement of straight lines made up of uniform dots. Continuous similarity ratings and speeded classification tasks were used in that study. Subjects were required to compare pairs of stimuli either identical in number and different in spacing, or identical in spacing and different in the number of elements. Meanwhile, subjects performed a sorting task. The results of that experiment indicated that a group of dots located distantly were seen as individuals whose organisation made an imaginary line. On the other hand, when the local components were located close to each other, or the number was large, they lost their status as individual parts. In the latter case local dots were perceived as the imaginary parts of a real line. In fact with decreasing the number of elements and increasing the spacing between them, they became more salient, but the lines made up of these dots were less salient and less integral. Klein and Barresi (1985) concluded that when the number of elements of a global configuration was few, they were perceived as individuals arranged into a global form. However when there was a large number of local elements, they were not perceived as individuals, but as elements out of which the global configuration was made. Therefore, it may be concluded that local components are integral parts of a global configuration if their numbers are few, but they are perceived as separable entities when their numbers are many.

Kimchi (1992) studied the effect of density/sparsity from the view of the "goodness" of global configuration, by changing the number of local elements embedded in the compound pattern. According to this study a global configuration composed of a large number of local elements looks better than the one that consists of few local components. Lasaga and Hecht (1991) differentiated between spacing (i.e., density/sparsity) and pattern goodness. According to these workers goodness of a shape is similar to the reflection of the quality of cohesion, but density reflects the intensity or strength of the cohesion. It seems that there is no direct correspondence between density and goodness of a pattern. Therefore, a good global pattern may be dense or sparse. The

variation in density does not necessarily affect goodness of a shape. Lasaga and Hecht's study demonstrated that smaller spacing produced fewer feature errors and more illusory conjunctions. The effect of spacing was explained by these workers in terms of a greater sensory limitation in the periphery than in the fovea. According to these workers good patterns decrease the level of foveal attention from the integration and not from the identification of local elements. Therefore illusory arrangements are more likely associated with good global shapes than with poor ones.

Generally speaking it may be argued that there is no consistent density/sparsity effect independent of other factors such as contours of the global figure, task demands, and the type of the stimulus. Therefore, it may be concluded that the global precedence is not necessarily associated with compound patterns composed of dense components, and it partly depends on the type of stimulus pattern and global-local relationship. Using Navon's (1983) words, it may "sometimes take as few as four trees to make a forest" (p. 253). Density/sparsity is not a variable of major concern in this thesis. The only experiment in which density/sparsity was manipulated was Experiment 1. Although there are some studies in the literature regarding the effect of density/sparsity, the interaction of this factor with other variables such as type of compound pattern needs further investigation.

2.4.4 Number of Elements

Density/sparsity and number of elements are closely related concepts. Since it is possible to keep the sparsity of a compound pattern constant, with decreasing size of the compound pattern, 'number of elements' will be discussed under an independent topic. When number of elements of a compound pattern decreases, the resulted sparsity may make the global figure less recognisable. For example, Navon (1983) argued that the so called global precedence can be reversed when the number of elements is considerably small. The reason provided by Navon was simple; letters made up of few elements may hardly match with the prototype people have from that letter.

Number of Elements and Percepts of the Global and Local Levels: Number of elements has been suggested (e.g., Kimchi, 1982, 1988, 1992; Kimchi & Palmer, 1985) to affect perception of the global and local levels. Kimchi in her various works proposed that the global/local relationship is influenced by number and size of the local elements. Compound patterns composed of many small elements are perceived as global configurations with local molecular texture, whereas patterns made up of few and relatively larger elements are perceived as global configurations with figural parts. Kimchi (1992) suggested that few-element stimuli are better suited for the global precedence experiments than many-element stimuli, because the local components and overall form of these patterns appear to have the same psychological reality, while, the local elements of many-element stimuli do not seem to be perceived in the same way. The results of this study suggested that the percepts of the global configuration may not directly correspond to two geometrical levels of the stimulus. Mapping of these two levels into meaningful perceptual levels seems to be dependent to the number and relative size of the elements.

Task Requirement and Number of Components: The extent of the effect of number of elements on the distinctiveness of the global configuration of a compound pattern also depends on the task requirement. It seems that the global advantage and interference in a same/different task do not necessarily rely on number of local components, rather it depends on the stimulus type. However, in a recognition or similarity judgement task performance is probably affected by number of elements. For example, Navon (1983) indicated that performance in a similarity/difference task depends on the shape of the stimulus pattern, rather than number of elements.

Based on the classification of compound pattern provided in the previous chapter, variation in number of elements of a compound pattern can also affect the global-local relationship (Kimchi, 1992; Lasaga, 1989; Pomerantz, 1983). For example, number of elements is a major factor varying between hierarchical patterns of placeholder and inclusion types. Although, this factor is not manipulated in this thesis, it was indirectly

tested by the comparison of responses to compound patterns of placeholder and inclusion types.

2.4.5 Exposure Duration

To prevent eye movements, the stimulus exposure duration in experiments of the global precedence hypothesis is usually restricted to 150 msec (Findlay, Jacobs, & Brogan, 1988; Sergent, 1983a). However, it is suggested that fine details of a visual image become discernible later as energy is summed sufficiently (e.g., Eriksen, Goettl, St. James, & Fournier, 1989; Eriksen & Schultz, 1978; Eriksen & Yeh, 1985). Therefore, it may be argued that short presentation of a stimulus does not provide equal opportunities for the perception of the global and local levels. The effect of the exposure duration of a stimulus has been studied from various aspects. For example, Kitterle & Rysber (1976) showed that the shape of the contrast sensitivity function varies with exposure duration. Sergent (1983b) showed that hemispheric functioning is related to exposure duration of the stimulus. That is the exposure duration of the stimulus affects differentially the right or left hemispheric superiority. Rizzolatti and Buchtel (1977) reported that a decrease in exposure duration from 100 to 20 msec results in an increase in the right hemisphere superiority. This superiority was not associated with a faster RT, but was the result of slower left hemisphere functioning indicating that short exposure duration is more detrimental to the processing of the left than the right hemisphere.

Decreasing the exposure time, according to some workers (e.g., Navon, 1977), may have more degrading effect on the local information than the global. In Navon's (1977) study the stimulus was projected for a brief time in one of the four parafoveal locations and it was immediately followed by a mask. Therefore, it may be suggested that it is the effect of the short exposure duration of the stimulus and not the presence of any order in the processing of the global and local levels which produces the global advantage or global interference. The fact that short duration of the stimulus affects local components more than global configurations suggests that the global level is processed faster than the local level. This possibility has been suggested by some workers. For

example, Wandmacher and Arend (1985) proposed that if the stimulus is projected for a long duration, the global advantage will disappear. Lupker (1979) found that a very short exposure of letters and letter-like symbols are more confused with each other when comparison is at the global level than when the comparison is at the local level, and exposure duration of the stimulus is very short.

Paquet and Merikle (1984) conducted an extensive study on the effect of stimulus duration and the global/local interference effect. The results of this study suggested that the asymmetric interference effect is not a valid hypothesis at least for long exposure durations. Although a global interference was confirmed when the stimulus duration was 10 msec, for longer exposure durations both global and local interferences were observed. On the other hand, stimulus duration showed a direct effect on the quality of global and local information which was related to the spatial frequency. It seems that the quality of low spatial frequency is unaffected by exposure time, therefore, the available information was sufficient for the identification of the global form. However, the quality of available information for high spatial frequency varied by variations in the exposure duration. The identification of local forms required longer display time in comparison to the global forms (Paquet & Merikle, 1984). The results of this study also showed that the difference in the response times to the global and local levels increased with a decrease in the exposure duration. Meanwhile bi-directional interference with the long exposure duration was found regardless of the global advantage. Paquet and Merikle suggested that for short stimulus durations the required time for the recognition of a local letter was extended, and as a result global precedence was observed. However, with longer exposure time, recognition of local form is facilitated by the more complete integration of the higher spatial frequencies.

However, the effect of duration of the stimulus on the global/local advantage and interference was not confirmed by all workers. Ballesteros (1989) proposed that effects of manipulating the exposure time are limited by the nature of stimulus dimensions used. Navon (1991) reported that global advantage is insensitive to the display time which seems to be a sensory parameter. Luna, Merino, and Marcos-Ruiz (1990) studied the

effect of exposure time on 'global precedence' in speeded classification and identification tasks. In the speeded classification task the stimulus was terminated by the response of subjects and no mask was used, but in identification task the exposure time was limited and the stimuli were masked. The eccentricity and spatial certainty of the two tasks were controlled. Luna, Merino, Marcos-Ruiz found strong global dominance in both limited and unlimited exposure times.

The summary of the existing literature on the effect of duration of the stimulus suggests that increasing the stimulus duration probably results in a bi-directional interference of the global and local levels. However, there is not much evidence with regard to the change of the direction of global/local advantage due to the exposure time of the stimulus. The control of possible eye movements was of special concern in the experiments conducted in the present research. Therefore although there was the possibility that global interference may be affected by the short exposure duration of the stimulus, stimulus display time was limited to 100 msec in 9 experiments out of 12 experiments. In one experiment the stimulus was displayed for 16 msec, and in the other 2 experiments the exposure duration was 50 msec.

2.4.6 Visual Fields and Hemisphericity

The stimulus projected to different hemifields and various locations within a visual hemifield may be processed differently (Hubel & Wiesel, 1962, 1968). It has suggested that right hemifield (left hemisphere) is less affected by retinal eccentricity than left hemifield (right hemisphere) presentation. Marzi, Di Stefano, Tassinari, and Crea (1979) found no difference between the right or left visual fields using a single letter stimulus. However, they reported that compound patterns show a right visual field (RVF) superiority for the less peripheral stimuli and a left visual field (LVF) advantage for more peripheral locations. Sergent (1983a) also suggested that the right hemisphere is more adept than the left in processing information on peripheral locations. Sergent (1983b) reported that the RH may demonstrate superiority to the LH when the quality of information does not reach a sufficient level of clarity and acuity. From this logic RH

advantage (i.e., LVF) can be predicted for local components when the stimulus is projected to the larger eccentricities.

Upper, Lower, Right, Left Visual Fields: Previc (1990) suggested that upper and lower visual fields are specialised for local and global processing, respectively. Previc's explanation of this differentiation between visual fields is based on an ecological description of normal vision. He argued that objects located nearer to an observer tend to be located lower in the visual field because the visualisation of near objects is usually associated with some kind of visuo-motor manipulation, such as grasping and reaching. Processing of near objects is usually global because of the fact that the image of hands while reaching is both blurred and diplopic (Previc, 1990). On the other hand, the upper visual field plays a dominant role in far vision, because more distal objects are typically located in high locations. Previc suggested that the upper visual field is specialised for local processing, because processing of far objects involves a finer search for details. Previc's interpretation seems to be too speculative, but it shows the importance of the issue and a need for further investigation.

Christman (1993) conducted an experiment with stimuli similar to those stimuli used by Navon (1977), large letters made up of small letters. Christman presented the stimuli randomly to one of four visual fields, right, left, up, and down. Hand of response and target identity were counter balanced across subjects. These results provided support for the hypothesis that upper and lower visual fields are differentially specialised for the processing of local and global information. When the target letter was embedded at the global level, there was a trend toward the left and lower visual field advantage. On the other hand, when the target was presented at the local level, performance was better only in the upper visual field, but there was not any significant difference between the reaction times to the right and left visual fields. This study indicated an upper versus lower visual field advantage in the processing of local versus global information, respectively. The difference between the findings of Christman (1993) and neuropsychological evidence suggested by some workers (e.g., Robertson & Lamb, 1991) on the specialisation of the

right versus left visual fields for processing of local versus global levels, respectively, can be related to absence of control on eye movements in these studies. One of the important issues regarding the study of visual field and hemispheric superiority is that eye movement as a potential source of confound is not usually controlled in these studies. To the best knowledge of the writer of this thesis, this confound has not been controlled in the majority of studies on the relationship between visual field advantage, hemispheric superiority, and global/local processing. Visual field is one of the main factors which will be experimentally investigated in this thesis. In fact one of the thrusts of the present study is to test the role of right and left visual fields, and right-left hemispheres in the processing of the global and local levels of compound patterns.

2.4.7 Eye Movements

The two cerebral hemispheres of the human brain are supposed to be asymmetric due to variations in cognitive tasks. One method for the study of the hemispheric asymmetry is lateral eye movements. Kinsbourne (1972) found a right shift in eye movement (for right handers) when subjects were questioned verbally, and a left shift when they were confronted with spatial questions. However, Wilker, Wiemers, Weiß, & Becher (1987a) did not find a difference in the pattern of eye movement directionality due to verbal stimulus versus spatial location of the stimulus. There is also evidence on picture and face recognition indicating that the more salient side of a face is the right side (e.g., Wilker, Wiemers, Weiß, & Becher, 1987b). Therefore, the right or left visual field laterality may be associated with a preference to move the eyes to the right or to the left. Some eye movement researches, however, have not found a strong relationship between hemispheric laterality and the pattern of eye movements. For example, Brysbaert and D'Ydewalle (1987) argued that the asymmetry of perceptual span is mainly due to attentional factors rather than cerebral asymmetry.

Large eye movements have been extensively studied over the years. One important limitation to remember is that in very rapid reading or, a very rapid inspection of an object, the rate at which eyes can move has been found to be between four and five times

a second (Gaarder, 1975). The research literature on eye movements (e.g., Findlay, Jacobs, & Brogan, 1988; Fischer, 1992; Jonides, 1983; Tole & Young, 1981) indicates that the necessary time for to a single step movement of the eye to a target position is typically from 120 to 300 msec (Tole & Young, 1981). However, if the initial saccade misses the target, subsequent corrective saccades may occur with shorter latency. The reaction time for normal voluntary saccades, according to Tole and Young, is separated by a minimum of about 200 msec.

To the best of knowledge of the writer of this thesis, there is no report in the literature on the pattern of eye movements concerning processing of the global and local information. However, eye movements and the control of eye movements in the global precedence hypothesis seem to be a very important factor in forming patterns of responses to the global and local levels. In an experiment in which eye movements are not controlled, subjects may tend to move their eyes to the most likely location of a display or to a location which provides the optimum information about the target levels. Furthermore, an experimental design in which eye movements are not controlled is biased towards an attentional interpretation of the relationship between the global and local levels. The problem becomes important when experiments are conducted in a 'selective attention' condition. In this type of the experimental condition the identification of either global or local level is probably reduced to the detection of the most distinct local feature that might provide the greatest information (Navon, 1991). To control the possible confound of eye movements in the set of experiments conducted in this thesis eye movements were controlled using a technique in which subjects have to respond to the first and second fixation stimuli. The absence of control on eye movements in visual experiments may be associated with a phenomenon which is usually called range effect (e.g., Coren & Hoening, 1972). According to the latter view the concept 'range effect' refers to overshooting of saccades to near targets and undershooting to targets presented in further eccentricities (Kapoula, 1985). Range effect is a factor that will be examined in series of experiments discussed in Chapter 4.

2.4.8 Lateral Masking

The delay caused by the presence of other figures on the perception of a stimulus may occur for different reasons. Utilizability of a group of figures may be due to the encoding of the entire display as a unit and the serial encoding of the components. On the other hand, the unrecognizability of a stimulus may be related to the initial failure to provide a utilisable representation of the global configuration. According to Johnson (1986) an individually presented stimulus can be identified better than the stimulus presented within an array of the same or different noise letters. Lateral masking or the decrease in the likelihood of correctly identifying a target when it is surrounded by other items, has been suggested (e.g., Banks & White, 1984; Bouma, 1970; Mackworth, 1965; Wenderoth & Beh, 1977; Wolford & Hollingsworth, 1974; Wolford & Chambers, 1983) to affect the perception of visual stimuli. Wenderoth and Beh (1977) examined the effect of lateral inhibition in the orientation and position domain of components of a grating. Blakemore, Carpenter, and Georgeson (1970) suggested that tilt illusions and aftereffect may originate from the lateral inhibition between the orientation of selective channels in the V1 visual cortex. Lateral masking seems to be a composite of several processes: response competition, distribution of attention, perceptual grouping, and feature (contour) interaction (Wolford & Chambers, 1983). Dispositions of lateral masking can be classified as follows: (1) lateral masking is stronger in the peripheral vision than the foveal; (2) the effect of masking decreases with the increase in spacing between the target and mask and; (3) masks located on the peripheral side of a target are more effective than a mask placed on the foveal side (Wolford & Chambers, 1983).

Spacing: It seems that lateral masking has qualitatively different properties due to the distance of the target and mask. Wolford and Chambers (1978) suggested that the masking effect with close spacing between stimuli shows some sort of feature interaction dominance over grouping effects. However, when the spacing between the target and mask becomes wider, the lateral masking effect becomes inconsistent with featural interpretations and seems to be related to the distribution of attention. These workers

proposed that closeness of spacing is a function of the retinal eccentricity of the target. In most foveal locations, features interact over a very short separation, whereas the necessary distance for interaction at peripheral locations is fairly large. Bouma (1970) estimated that the distance over which target and mask interact is about half the target's eccentricity. Murphy and Eriksen (1987) found that when the subjects know where the target letter appears the interference of adjacent letters on the response time to a target letter occurs if flanking letters were within the 1° visual angle of the target letter. However when the subjects are uncertain about the location of the target letter, interference from the neighbouring letters is effective up to 2° - 3° from the location of the target.

Masking and the Global Precedence Effect: Based on the literature on lateral masking it seems reasonable to speculate that masking caused by the adjacent local figures of a compound pattern, may change discriminability, relative hue, or direction of local components (Pomerantz, 1981). Therefore, the relative response times to the global and local levels or global/local interference may be influenced by lateral masking of local components. However, as was mentioned that lateral masking may be influenced by retinal location and the spacing between the adjacent components. With the existing literature it does not seem reasonable to decide about the possible source and locus of lateral masking, whether it has a preattentive or postperceptual origin. Eriksen and Schultz (1978) showed that the identification of a target encircled by letters is facilitated if encircling letters are from the same response set as the target, whereas the response to the target letter is inhibited if it is surrounded by letters of a different response set. Therefore, lateral masking may be the result of response competition rather than the interaction of the features of a compound pattern. Although the variable of lateral masking will not be directly manipulated in the present study, the literature on this variable will be used to explain the results of the experiments explained in Chapter 4 of this thesis.

2.4.9 Retinal Location

Navon in his early works (1977, 1981b) utilised the exposure of the stimulus in any of the four parafoveal locations, and found global advantage and global interference in all locational conditions. Hoffman (1980), however, suggested that for a centrally fixed display the global and local levels have the same amount of interference with each other. The reaction times to the global and local levels in this type of presentation are not significantly different. Kawabata (1990) proposed that peripheral processing, which usually fills in the gaps among structural components of an image, produces 'structural patterns'. Such 'structural patterns' are assumed to be the result of omitting irrelevant aspects or adding some information to the group of stimuli. It has been suggested the pre-processed information which usually comes from peripheral vision plays an important role when high-speed of processing is required or when enough information is not available for processing (Goolkasian, 1981; Kawabata, 1990). Therefore, the global precedence effect may be influenced by retinal location (i.e., foveal versus. peripheral) of the stimulus (Lovegrove & Pepper, 1994). Pomerantz (1983) suggested that because of high acuity in the fovea, perception of centrally presented local elements is facilitated in comparison to perception of peripherally presented global configurations. However, the slower reaction times to peripheral stimuli in Pomerantz's (1983) study may originate from the confound of spatial uncertainty.

Lamb and Robertson's study (1988, Experiment 1) showed that the central presentation of the stimulus results in an increase in the reaction time to the global configuration and a decrease in the interference of the global level on the processing of local components. Lamb and Robertson in their third experiment controlled the effect of eye movements and concluded that the difference in patterns of responses to the central and peripheral presentation were not related to eye movement or to the use of masks. Generally speaking, the results of this study indicated that the central presentation facilitated the perception of local components. However, this type of presentation of the stimuli resulted in a decrease in speed of processing of the global configuration. On the other hand, the central presentation of stimuli did not facilitate the perception of individual

letters with the same size as local letters. In fact the central presentation facilitates the identification of small letters when they were located within a hierarchical pattern. Therefore, it was suggested that visual uncertainty was not the source of the difference in patterns of results in Lamb and Robertson's study.

On the other hand, some other studies emphasised the faster or more accurate response to peripheral than central stimuli. For example, experiments on the outside-in paradigm have demonstrated that peripherally displayed figures suffer less from the interference of the adjacent figures than focally presented figures. In contrast, peripherally presented outside lines of a compound pattern are possibly processed faster than the focally displayed inside line segments (Earhard, 1990; Earhard & Walker, 1985). Generally speaking, some studies reported that peripheral presentation of the stimulus increases global rather than the local advantage. However, we do not know whether this increase is because of the difference between central versus peripheral vision or it is related to the status of the levels in the hierarchical pattern (i.e., global versus local). The existence of controversy in the literature and lack of control on the confounds of size, eccentricity, and eye movements in the literature require more sensitive experimentation. However before the experiments that were undertaken to study the effects of size and eccentricity are reported, some attention will be given to the available literature on the effect of eccentricity. In the next section instead of a crude and general differentiation between central and peripheral retinal locations, eccentricity will be discussed in more detail.

2.4.10 Eccentricity

The global/local advantage and global/local asymmetry are suggested to be related to eccentricity (e.g., Luna, Merino, & Marcos-Ruiz, 1990; Navon & Norman, 1983). However, the extent of the influence of this variable has not been studied precisely. Perhaps the only study in the global precedence paradigm in which the effect of eccentricity was controlled was Navon and Norman's (1983) experiments. To control the eccentricities of the global and local levels, Navon and Norman examined the global precedence effect

using stimuli whose elements were located around their periphery, large Cs composed of small Os, or large Os made up of small Cs (Figure 12). Although eccentricity was controlled in that study, the extent of the effect of this factor was not examined. However, they speculated that the response time to a stimulus decreases with increasing the eccentricity.

Shulman, Wilson, and Sherehy (1985) studied the effect of eccentricity using a simple RT technique that did not involve acuity limitations. In this study subjects were cued to attend to either a foveal or a peripheral light. The results indicated that the speed of processing decrease with an increase of the distance of the target light from the focus of attention. Meanwhile, it was revealed that the effect of attentional manipulation of central cues is more than peripheral cues. Shulman, Wilson, and Sherehy suggested that the slope of distance from the fovea is the reflection of the size of the attentional field. The increase in reaction time to events away from the centre of the focus should not be as much as the increase in RT for the events which occur in short distance away from the centre. Therefore, according to these workers, the slope of changes in reaction time by distance is an indicator of the attentional field size.

Interpretation of the RT Variations Across Eccentricity: Variations in RTs across eccentricity may be interpreted in two main ways. According to the first interpretation attention is suggested to be the origin of variations across eccentricity (e.g., LaBerge, 1983, LaBerge & Brown, 1986). In a typical example, subjects are instructed to identify the central stimulus of a string. Then a second string of characters is presented. The task is to identify a specific target located in one of the positions of the second string. It was suggested that the reaction time shows a V shape function according to the target location, where centre of the V coincides with the centre of the attention (LaBerge, 1983, LaBerge & Brown, 1986). The V-shape function of the response time to the stimulus located at different positions of a string may be explained by shifting the focus of attention (e.g., Eriksen & Yeh, 1985) or as a gradient of processing capacity (e.g., Shulman, Wilson, & Sherehy, 1985). According to the shifting focus theory when the target appears at the

central location, reaction time is minimal because no shift of attention is required. This theory suggests that the "velocity" of the shift is constant, and reaction times to stimulus sets of different visual field sizes lie on the same curve. The reaction time increases with an increase in the distance between the focal point and the target. On the other hand, the gradient theory suggests that RTs are affected by the range of the visual field, and the response times for the different target ranges lie on different curves.

Opposing the generalisability of shifting focus and gradient theories LaBerge and Brown (1986) suggested that other attentional factors dominate the processing of visual targets. According to these workers factors related to retinal sensitivity, such as the decrease of acuity at peripheral locations, play a minor role, if any, in visual processing. LaBerge and Brown suggested that narrowing the range of expectations to a target (i.e., decreasing the possible range of the visual field or eccentricity) does not necessarily result in a faster response. In a study conducted by these workers subjects were required to respond to a target embedded within a pair of vertical lines. The target was displayed in one of five locations within a particular horizontal range. There were five ranges, from 1.7° to 8.6° . Pattern of RTs to the target exhibited a V-shape curve, with the lowest RT to the initial point of attention. The response times at the extreme locations of the five ranges showed no significant increase with eccentricity. These results suggested that the influence of variations in eccentricity is negligible, in comparison to attentional factors.

In another study by LaBerge (1983) subjects were required to categorise (a) five-letter words, or the middle letter of (b) five-letter words or (c) five-letter nonwords. The task was to respond when a digit appeared in one of the positions of the string of five letters. Probe trials produced a V-shape function of RTs across probe positions. In contrast a relatively flat function was obtained for a word categorisation task. LaBerge interpreted these results according to the width of attention spotlight. The spotlight width was one letter space in the letter task and five letter spaces in the word task.

According to the second interpretation, variation in the response times across eccentricity is the result of a physiological or psychophysical factor. For example, it was suggested that density of cone receptors decreases at the peripheral locations (Yellott,

Wandell, & Cornsweet, 1984). Polyak (1957) reported that the density of cones at a location 5° from the fovea is about 1/10 of that at foveal location, where the receptor density is maximum (Osterberg, 1935). Studies on the effect of retinal locus on visual perception have indicated that peripheral vision reduces acuity markedly (e.g., Eriksen & Schultz, 1978; Sergent, 1983). Millodot (1966) reported a decrease of 50% in acuity at an eccentricity of 2° in comparison to the fovea. Therefore it may be suggested that because of this sharp decrease in the density of visual cells the reaction time increases as the image of a stimulus moves from the fovea towards the periphery. A similar explanation has been suggested by spatial frequency hypothesis, where speed of processing at peripheral in contrast to focal locations is attributed to the speed of processing in low and high spatial frequency channels, respectively (Badcock, Whitworth, Badcock, & Lovegrove, 1990; Kinchla & Wolfe, 1979; Navon, 1977; Weisstein, Maguire, & Brannan, 1992). It should be further added that despite the difference in the interpretation of the origin of eccentricity effect both of the above mentioned views suggested that the reaction time to the identification of a stimulus decreases with an increase in eccentricity. Since the centre of attention was cued to the centre of the stimulus array according to the first view, the V-shaped function of the reaction time means nothing more than a decrease in the speed of processing either to the right or to the left of the fixation point. Because, the centre of the V was at the fovea.

Eccentricity and Visual Field: It seems that eccentricity interacts with the visual field. A right visual field advantage was reported (Sergent, 1983a) for pairs of letters when they were projected to the eccentricity 2.5° and a left visual field advantage was reported when the same stimuli were projected to eccentricity 11° . The switch between the two visual fields was not found below 4° (Sergent, 1983b). Using Posner's (1975, 1978, 1983) paradigm (matching pairs of letters of the same or different case or name) Sergent (1983b) found that RTs decrease with a decrease in eccentricity. Although subjects responded faster to the stimuli projected to the left visual field (LVF) than to the

right visual field (RVF), this difference was not significant. However, the interaction between eccentricity and visual field was significant.

To the best knowledge of the writer of this thesis literature on the effect of eccentricity on global/local processing is indirect. In none of the studies I am familiar with, has global/local processing been studied across a wide range of eccentricity. The result of the studies mentioned above suggest the view that an increase in eccentricity will probably increase reaction times to either the global or local levels. This decrease the speed of processing may have attentional or physiological origins. The absence of a comprehensive study on patterns of results to the global and local levels across eccentricity was the main motive in developing the series of experiments to be discussed in Chapter 4 of this thesis.

2.4.11 Spatial Uncertainty

Theories of pattern vision have demonstrated that the visual system is selectively sensitive to the spatial frequency and position of the stimulus (e.g., Cohen & Lasley, 1974; Davis & Graham, 1981; Davis, Kramer, & Graham, 1983; Posner, 1978). Treisman and Gelade (1980) found a higher probability of locating a target when subjects were certain about the identity of the stimulus. Pelli (1981) suggested that detectability of a briefly presented line was slightly affected by the locational uncertainty and exposure duration of the stimulus. Farell and Pelli (1993), however, proposed that identification of a stimulus is insensitive to uncertainty to the size of the stimulus. Engel (1974) also found no difference in the detectability of dots presented at a known location and those that were displayed at unknown locations. However, a large number of studies have reported a decrease in performance when subjects were uncertain about the spatial frequency or spatial position of the stimulus (See, Davis, Kramer, & Graham, 1983, for a review). For example, Howard (1982) suggested that when a target appears at an expected location, the reaction time to that target decreases because attention is already aligned with the source of input (Howard, 1982).

Grice, Ganham and Boroughs (1983) examined the generality of the global precedence effect in a situation appropriate for the clear perception of small letters. The experimental conditions according to the consistency of target letters and noise letters were three: same-letter, irrelevant, and response incompatible noise. These workers suggested that with a fixed stimulus location, RTs to both large and small letters did not differ significantly. However, when subjects were uncertain about the location of the stimulus, the results provided clear demonstration of the global precedence effect. According to these workers any factor which may degrade local components more than the global configuration will tends to produce global precedence effect. These factors include variables such as uncertainty of the position, location on the retina, exposure duration, masking and clarity.

It has been argued that spatial uncertainty in comparison to spatial certainty may force a subject to attend to a larger area (e.g., Kapoula, 1985). Therefore, the response to a stimulus which is displayed in an uncertainty condition is longer than the response to that stimulus when it is displayed at a predetermined location (Hughes, Fendrich, & Reuter-Lorenz, 1984). The expansion of attention may be more compatible with the perception of the global and not the local level.

In summary an inherent problem regarding the identification of the global and local levels of a compound pattern is whether subjects confined their attention to a fixed position as a local component of a stimulus or they extended it across the global configuration. As Navon suggested, if subjects aimed their beam of attention just at a single letter, in that case, a local feature is used to identify the global configuration. One way to deal with this difficulty is introducing spatial uncertainty in a 'selective attention' paradigm. However, a problem which may arise from application of spatial uncertainty is that it may lead to an attentional bias in favour of the global level. An increase in the reaction time to the detection of a visual target when it appears in an unexpected location has been attributed to the alignment of an attentional mechanism with the source of input (Hughes & Zimba, 1985). According to this view the increase in the reaction time to a stimulus appearing in an unexpected location occurs because attention has to move from

an expected to an unexpected location (Hughes & Zimba, 1985). The assumption underlying this view is that attention has a spatial limitation. Taking all these controversial findings into account it may be concluded that the response time to the processing of the global or local level increases with the increase in the spatial uncertainty to the stimulus. Navon (1991) proposed that locational uncertainty generates sensational bias. However, it seems that the existing data on locational uncertainty effect is more compatible with attentional explanation. Whether locational uncertainty changes the direction of global/local precedence is an issue which needs more investigation. Spatial certainty/uncertainty will be studied in series of experiments which were undertaken and reported in Chapter 4.

2.4.12 Size

From all factors affecting global advantage, overall visual angle of the hierarchical stimulus is the most controversial one. Kinchla and Wolfe (1979) proposed that with increasing the visual angle of hierarchical patterns global advantage changes to local advantage about the visual angle 6° to 9°. This finding can be supported and interpreted by some physiological findings (e.g., Blademore & Campbell, 1969; Lefton & Haber, 1974) on the existence of neurones in human visual system selectively sensitive to the orientation and size of the stimulus. Meanwhile Lamb and Robertson (1990) stated that the reversal point reported by Kinchla and Wolfe depends on the arrangement of the visual angles of the stimulus set. The transition from global advantage to local advantage in Lamb and Robertson's study occurred between 1.5 and 3 degrees in one stimulus series and between 3 and 6 degrees in the other. From these results they concluded that the visual angle at which the transition occurs depends on the arrangement of the set of visual angles presented to the subject. The larger the stimuli in the set, the greater the visual angle at which the transition occurs. According to these workers global advantage is mainly influenced by upper visual mechanisms such as attention. However, in a critique of Kinchla and Wolfe (1979), Navon and Norman (1983) stated that former workers confounded globality and eccentricity. Due to the latter workers, if the

eccentricities of the two levels are controlled, the global configuration will be responded to faster than the local level because it is larger than the local level.

Wandmacher and Arend (1985, Experiment 1) studied the effect of size using triangles or arrows composed of horizontal, vertical, and oblique lines (Figure 4). This type of stimuli was already used by Pomerantz (1983, Experiment 5). The results of Wandmacher and Arend's study demonstrated a global superiority in a classification and matching tasks, where the local features had almost the same spatial extent as the global configuration, and where the local components were structurally relevant to the global level. Antes and Mann (1984) studied the effect of size with stimuli whose global and local levels had semantic relationship with each other. They found a reversal point in direction of global/local advantage similar to the finding stated by Kinchla and Wolfe (1979). Antes and Mann's explanation of the sequence of processing was very similar to Kinchla and Wolfe's "middle-out" model of processing. Antes and Mann suggested that there is a critical sampling bandwidth (range of sizes or spatial frequencies) from which the processing is initiated. When the compound pattern is small spatial frequencies of the global configuration may fall within that sampling bandwidth. However, when the stimulus is large its spatial frequency is probably too large to be located in that bandwidth. Antes and Mann verified the initially processed spatial frequency bandwidth to be approximately three to eight contour changes per degree of visual angle, irrespective of the target level to be processed.

Two major studies have been conducted on the effect of size in the global precedence hypothesis. According to the results of Kinchla and Wolfe's study absolute size of the compound pattern is the determinant of the global advantage. Navon and Norman (1983), however, proposed that relative size is the determinant of the global advantage and interference effects. Obviously, any variation in the size of a compound pattern may differentially affect eccentricities of the global and local levels. The only study in which variation in size was studied in a condition in which eccentricity was controlled, was Navon and Norman's study. However, this study was conducted in size/eccentricity certainty conditions and only with compound patterns of placeholder

relationship. Due to the existing controversy in the literature and lack of sensitive and well-controlled experiments, the effect of size will be experimentally investigated in this thesis using compound patterns of placeholder and inclusion relationship.

Eccentricity and size effects can be explained in terms of spatio-temporal properties of known visual mechanisms, transient and sustained channels. In continuation of this chapter explanation of the so the called global precedence effect will be elaborated regarding the spatial frequency properties of visual perception.

2.4.13 Spatial Frequency

It has been proposed (e.g., Breitmeyer and Ganz, 1976 & 1977) that there are two visual subsystems: transient and sustained. The transient system is specialised to low spatial and high temporal frequencies and sustained system is adopted to high spatial and low temporal frequencies. Also it has been suggested that there are cells in our visual field that are selectively responsive to different bands of spatial frequencies (Breitmeyer, 1984; De Valois & De Valois, 1980; Graham, 1981; Shapley & Lennie, 1985). Similar argument has been made (e.g., Weisstein, Maguire, & Brannan, 1992) using physiological difference between the so called magnocellular and parvocellular pathways and perceptions of low and high spatio-temporal properties, motion, depth, and clear figure/ground segmentation. It has been suggested that parvocellular pathways are more responsive to low temporal frequencies, perceptions of fine details and colour. On the other hand, high spatial frequencies mediated by magnocellular cells are involved in edge perception and resolution of details. Studies in this field provide evidence that early in visual processing a coarse Fourier decomposition occurs and different pieces of the spectrum are processed by independent channels.

Similar to the global-local relationship an important issue regarding spatial frequency channels is speed and order of processing of the two channels. It has been suggested that the activity in transient channels inhibits the activity in sustained channels (Breitmeyer & Ganz, 1976; DeValois & De Valois, 1980; Hughes, 1986). Hughes (1986) found that choice reaction times to low spatial frequencies are not affected by the

presence of high spatial frequencies. However, reaction time to high spatial frequencies was decreased by the presence of low spatial frequencies. Type of stimulus onset, gradual versus abrupt, also influenced the magnitude of low spatial frequency interference in that study. Low frequency interference increased when the stimuli were presented abruptly rather than gradually. The results of that experiment showed that inhibition caused by channels tuned to low spatial frequencies on channels tuned to high spatial frequencies was more than the inhibition caused by high on low spatial frequency channels (Hughes, Layton, Baird, & Lester, 1984).

Global/Local Processing and Spatial Frequency Channels: It has been suggested that early visual processing is mediated by mechanisms that are selectively tuned to different spatial frequency channels which operate independently and in parallel (e.g., Kelly & Burbeck, 1984; Lennie, 1980; Shapley and Lennie, 1985; Stromeyer, Julesz, 1972). Fast conduction feature of low spatial frequencies has been proposed as the explanation for earlier or faster encoding of the global information (e.g., LaGasse, 1993; Navon, 1977; Shulman & Wilson, 1987). For example, Hughes, Fendrich, and Reuter-Lorenz (1990) suggested that the spatial properties of global and local levels might be encoded by high and low spatial frequency channels, respectively. Therefore, they speculated that the dominance of global over local spatial cues might be attributed to either faster processing of low spatial frequency channels or inhibition of high frequency channels by a mechanism tuned to lower spatial frequencies.

The role of low spatial frequency in the processing of global image has been the subject of some studies. The corner stone of these studies is the assumption that if the global advantage effect depends on mechanisms tuned to low spatial frequencies, removal of low-frequency bands will reduce global advantage. To produce a stimulus that significantly tuned to low frequencies, Hughes, Fendrich, and Reuter-Lorenz (1990) constructed patterns consisting of small bright spots surrounded by a darker annulus. The results of their experiments indicated that global advantage is evident only for the displays

containing low spatial frequencies. Stimuli composed of dots largely devoid of low frequency content showed local advantage.

Shulman & Wilson (1987) found that attending to the global level enhances the detectability of an unattended low spatial frequency grating, whereas attending to the local target improves the detectability of an unattended high spatial frequency grating. Badcock, Whitworth, Badcock, and Lovegrove, (1990) tested the hypothesis that if rapid transmission of information is due to faster transmission of information in low spatial frequency channels then this precedence will disappear when these frequencies are removed from a stimulus. Large letters made up of small letters were used as stimuli. This type of stimuli ordinarily contains a broad range of spatial frequencies. The results of this study showed that after filtering low spatial frequencies the global pattern remained still obvious and RTs to both global and local levels did not change. This may suggest that global patterns may be perceived by grouping the output of high spatial frequency channels (Badcock, Whitworth, Badcock, & Lovegrove, 1990). The results of this study also indicated that low spatial frequencies are responsible for high speed of global information.

Other studies (e.g., Antes & Mann, 1984; Kinchla & Wolfe, 1979) have indicated that the relationship between global-local processing and low-high spatial frequency channels is not monotonic. An optimal spatial frequency band has been suggested in these studies. The spatial frequency of either of the global or local levels that falls within this band is supposed to be processed faster than the other level. For example, Antes and Mann (1984) proposed that there is an optimal bandwidth of size or spatial frequency from which the initially processed level of a form is selected. Subsequent processing of the stimulus can occur either at higher or lower level. Antes and Mann (1984) suggested that optimal number of changes per degree of visual angle for rapid perceptual processing is approximately between three and four cycles per degree.

Eccentricity and Spatial Frequency: It seems that there is a relationship between sensitivity of the retinal locations and spatial frequency of the stimulus. For example,

Tootell, Silverman, and De Valois (1981) reported that high spatial frequencies are absent beyond 5°. Performance on probe gratings of different spatial frequencies is influenced by the eccentricity of the primary task stimulus. For example, Shulman and Wilson (1987) indicated that for high frequency probes hit rate increases for foveal compared to peripheral letter locations. However, for low frequency probes hit rate decreases in foveal relative to peripheral locations. Some workers have explained variations across eccentricity using attentional factors. For example, Shulman and Wilson (1987) suggested that a possible explanation of low frequency advantage during a peripheral task is that as the attention became peripheral the attended area becomes larger. However, when people concentrate their attention at foveal a small fraction of low frequency cycles is perceived. In fact, as attention focus moves to the periphery it is spread over a larger area.

The global precedence hypothesis will not be studied in terms of spatial frequency properties in this thesis. However, they will be indirectly referred to concerning the concepts of size and eccentricity as spatial properties of a stimulus. In continuation of this chapter some other factors affecting global/local advantage and interference will be addressed. These factors will not be experimentally investigated in this thesis but they will be discussed as factors that need further investigation.

2.4.14 Similarity of the Global and Local Levels

Luna, Merino, and Marcos-Ruiz (1990) tested the effect of the degree of similarity between the global and local levels of the stimulus on global/local advantage. The idea behind this study was that a high degree of similarity between local and global levels decreases the discriminability of the two levels. This might affect the global/local advantage and interference. It should be clarified that the degree of similarity is different from the consistency that refers to whether the two levels are the same or different. Consistency was measured with stimuli whose local and global levels were the same or different. Luna, Merino, and Marcos-Ruiz manipulated the similarity using the criterion of symmetry axes. Circles and triangles were used interchangeably as local and global levels

of either consistent or inconsistent stimuli with a low degree of similarity; circles and squares as global and local level of stimuli with medium similarity; and square and diamond as stimuli with a high level of similarity. The results of their study suggested that RTs to the global and local levels increased with an increase in similarity. However, the direction of the global advantage did not change with variations in similarity. From these results Luna, Merino, and Marcos-Ruiz (1990) concluded that the similarity of the two levels does not change their temporal order of processing of the two levels.

Lamb and Robertson (1989) Also examined the possible covary of the global/local advantage and interference in a 'divided attention' condition using letter-type stimuli. The task was identification of target letter either at the global or local level. The target figure may be either in the global or local level. Lamb and Robertson's study was one of the few investigations which employed a 'divided attention' experimental condition to study the global/local interference, using stimuli with various degrees of similarity between their target and distractor levels. Letters "H" and "S" were selected as the target, and "A" and "E" as the distractors. It was assumed that letters "H" and "A" were more similar to each other than "H" and "S," or "H" and "E"; and the similarity of "S" and "E" was much more than the similarity of "S" and "H," or "S" and "A." Therefore, it was assumed that RTs to the target "S" would be faster when the unattended level was an "E" than an "A," and RTs to an "H" targets would be faster when the unattended level was an "A" than an "E." The results of this study showed a systematic increase in the interference effect with an increase in similarity relationships between the target and distractor stimuli.

The increase in interference of both global and local levels with an increase in similarity of the two levels reported in these two experiments suggests that response times to the identification of the global and local levels was influenced by the degree of similarity of the two levels. Meanwhile it can be concluded that the global/local interference may have an origin in the degree of physical similarity of the global and local levels.

2.4.15 Context Effect

Stins and van Leeuwen (1993) proposed that perception is regulated by the unconditional recognition of a fixed set of components and mandatory integration of them into higher order structures. According to these workers context effects occur when subjects employ an integrative perceptual organisation. The integrative perceptual organisation, according to these workers, refers to a strategy which is dictated by the task demands to compare local components with a global configuration concerning the global property of the part and not due to local properties. In a study conducted by these workers subjects were shown rapid sequences of a prime which was either a global configuration or a local component. The task was to decide if the third figure was a part of the second figure or if they were the same in relation to a dimension. The prime was assumed to establish a context for stimuli that followed to be compared with. The prime as a context influenced the global-local comparison. However, it did affect the comparison of the local feature with the respective local property of the whole. The results of this study demonstrated the importance of prior information in the perceptual organisation. When a prime was compatible with a part, with regard to their global structures, the subsequent identification of a local component in the global configuration was facilitated. This study demonstrated that the difference between local and global strategies was partly affected by the identity of the prime and context effect.

2.4.16 Stimulus Type

Type and identity of the stimulus may affect the processing of the global and local levels. For example, in a study conducted by Navon (1983) subjects were to make 'same-different' judgments on pairs of geometrical figures. With triangular patterns a global advantage was found which seems to be related to the relative size of the global and local levels. However, with rectangular patterns global advantage was not accounted for by the relative size, number of elements, or the spacing among elements. The results indicated that patterns of responses were related to the type of stimulus, triangular versus rectangular.

Speed of processing to different dimensions may be different. For example, in a study reported by Shepp (1989b) it was reported that colour was an easier dimension than form to be detected. Meanwhile, certain patterns may be identified better than the others. Lamb and Robertson (1988) found that global level is ignored easier when the local level was an S compared to an H. Also the level of Stroop-type interference in that experiment increased when the target was an S than a H. However, the reaction time did not change as the function of the letter-type. Therefore, the speed of processing and interference in that study did not covary. From these results Lamb and Robertson concluded that type of the target figure may influence the processing of the global and local levels. There is little information in the literature about the nature of the effect of the stimulus type. However, this effect seems to be an important source of bias.

2.5 Sources of Global/Local Advantage and Interference

There has been a good deal of controversy about the sources of global/local advantage and interference. Whether lower level sensory mechanisms such as retinal location or higher level mechanisms such as attention is the source of these effects has been the subject of many studies.

Discriminability Interpretation: One explanation of the source of the global precedence effect which has routes in common sense is based on the relative discriminability of global and local levels. Findings which indicate that presence or absence of global/local advantage and interference may depend on perceptual factors affecting the quality of information available at the global and local levels, support this argument. In the previous sections it was reported that factors such as density/sparsity of local components (e.g., Lovegrove & Pepper, 1994), number of elements (e.g., Kimchi, 1982), exposure duration (e.g., Wandmacher & Arend, 1985), luminance of the stimulus (e.g., Hughes, Layton, Baird & Lester, 1984), lateral masking (e.g., Wolford & Chamber, 1978), and retinal location (e.g., Kawabata, 1990) may affect processing of

global and local levels. According to this interpretation it has been suggested that (e.g., Hoffman, 1980; Kinchla & Wolfe, 1979; Navon & Norman, 1983; Pomerantz, 1981, 1983) the global configuration is superior to local components mainly because the latter are less discriminable than the former. Because of that Pomerantz (1981) suggested that if the relative discriminabilities of the global and local levels are matched, local elements will be processed faster than global properties. From these findings it has been suggested that global advantage and interference are mediated by the sensory system (Kimchi, 1992).

These findings have been supported by data on spatial frequency channels (e.g., Badcock, Whitworth, Badcock, & Lovegrove, 1990; Hughes, Fendrich, & Reuter-Lorenz, 1990). Perhaps the spatial frequency literature is one of the strongest arguments for the role of sensory mechanisms in global advantage and interference, although the possible role of attentional factors in processing of low and high spatial frequency channels has not been ruled out in this literature (Shulman & Wilson, 1987). It seems that early visual processing is mediated by mechanisms that are selectively tuned to different spatial frequency channels which operate independently (e.g., Kelly & Burbeck, 1984; Lennie, 1980; Shapley & Lennie, 1985; Stromeyer & Julesz, 1972). It has been suggested that there are cells in our visual fields which are selectively responsive to different bands of spatial frequencies (Breitmeyer & Ganz, 1976, 1977). The dominance of global over local spatial figures might be attributed to either the faster processing of low spatial frequency channels, or inhibition of high frequency channels by the mechanism tuned to lower spatial frequencies (Shulman & Wilson, 1987).

Attentional Interpretation: New developments in neuroscience have opened the study of attention to physiological analysis. Nevertheless, our knowledge of anatomy of attention is still incomplete (Muller & Rabbitt, 1989; Nelson, Early, & Haller, 1994). From the existing neurophysiological findings Posner and his associates (e.g., Posner & Dehaene, 1994; Posner & Petersen, 1990; Posner & Rothbart, 1992) examined principles of organisation that allow attention to function as a unified system for the control of mental processing. These workers provided a classification of attention system which

might be useful concerning global/local advantage and interference. According to this classification attention is divided into three subsystems that perform different but interrelated functions: (a) orienting to sensory events; (b) detecting signals for focal (conscious) processing, and (c) maintaining a vigilance or alert state. First type of attention proposed by Posner is a reflexive (bottom-up) mechanism and the second type refers to a directed (top-down) attention process. Aspect of Posner and Petersen's (1990) study that relates to differentiation between directed and reflexive attention may be important regarding the explanation provided in this thesis about the possible source of global/local advantage and interference. There is a possibility that global attributes might be captured by more global objects in an automatic fashion. This is a possibility that has not been examined in the literature of global/local advantage and interference and needs detailed inspection. The study of the effect of covert (reflexive) type of attention in the processing of global and local levels is not targeted in this thesis, however, it is a factor which needs consideration.

The finding that global precedence has a sensory origin does not rule out the effect of postperceptual processes such as attention and decision making (Kimchi, 1992). If global advantage and interference are found only in the 'divided attention' condition, it may be interpreted as a failure to concentrate attention on the local level rather than reflecting the activity of any sensory mechanisms. However if these effects are obtained in the 'selective attention' presentation condition, it may indicate that some sensory components are involved.

Some workers have suggested that attention can be effectively divided between two possible locations of a stimulus. For example, Müller and Findlay (1979) proposed that there is a preselective, parallel, and relatively capacity-free stage of visual perception. In this stage simple features of a stimulus and some aspects of meaning are processed. It is followed by another stage in which aspects of meaning are preserved and are formed as reportable perception. Müller and Findlay believed that the transference from the first to the second stage is serial and involves attention. According to this view global/local advantage and interference can be attributed to existence of a preferential system in an

attentional mechanism (in the second stage explained above) in favour of processing of global properties (Boer & Keuss, 1982). To identify whether processing of letters at the global level is influenced by the physical characteristics of the local information, Miller replicated Navon's (1977) experiment with large letters composed of small letters. His hypothesis was that if local letters had an influence on the processing of large letters, using different small letters would decrease the speed of processing at the global level. Miller found that the speed of processing in the global and local levels is determined by attentional processes and not by visual information extracted from the stimulus. According to Miller when attention is directed to both structural levels, the information coming from two levels is integrated by a single decision mechanism. Therefore, global advantage and interference can not be attributed to the order of availability of information, but it may be related to a difference in the ease with which attention can be directed to one level and excluded from the other one. In other words, it is possible to attenuate the weaker channel below threshold while leaving the stronger one above threshold, but the reverse is not valid. Therefore, Miller explains global precedence as being due to the priority in attentional processes. According to this worker, although physical aspects of the stimuli are important, attentional mechanisms seem to be the determinant of the so called 'global precedence effect'.

Some other workers (e.g., Robertson & Lamb, 1991; Robertson, Lamb, & Knight, 1988) have suggested that both attentional and perceptual processes contribute to the global/local analysis and can be affected independently by damage to different parts of the brain. Lamb and Robertson (1990) suggested that it is not reasonable to argue that local components are identified slowly simply because limited acuity makes local letters not to be as discriminable as large letters. Lamb and Robertson's study indicated the importance of both attentional and sensory factors in global/local advantage and interference. These workers proposed an attentional model. According to this model limited resources are allocated to different levels of stimulus structure. Therefore if attention is allocated to any of the levels, there will not be enough resources left for the other level. Robertson and Lamb suggested that the perceptual system responds to global and local levels in the initial

stages of processing independently. Robertson and Lamb (1991) proposed that different cortical regions are uniquely involved with the processing of the global and local levels. According to these workers attention allocation to the global and local levels can be affected independently from top-down cortical processes to generate a global or local advantage. These workers gave an example of a horse-race model between two processing channels. One analyses information that comes from the global and local levels and is probably influenced by the relative spatial frequencies of the two levels. The other distributes attention within these channels and modulates their output. The latter processing channel is probably associated with parietal lobe.

Concluding Remarks: With present research findings it is not easy to determine fully the source of global/local precedence. Part of the difficulty originates from difficulty in attributing subjects' subjective responses to perceptual processing at the functional level and the differentiation between reflexive and directed attention. Perception of hierarchical patterns seems to be a multidimensional process. Some of these processes are likely to occur early at perceptual or even sensation stages. Others are probably attentional in nature, and some may be influenced by still later processes concerned with decision making and response selection (Kimchi, 1990). Meanwhile, as Kimchi (1992) suggested, it partly originates from the fact that an effect manifested at a postperceptual level may have an preattentive origin. However, probably the most important issue is that order, speed, and relative salience of processing of the global and local levels are related to the type of a compound pattern. In addition as was indicated in this chapter, the performance measures of the 'global precedence hypothesis' do not covary. Therefore, these performance measures may be associated with different sources of global/local dominance. These issues will be investigated in a series of experiments. However before the experiments are reported, some attention will be given to a summary of the first two introductory chapters and rationale of the present study.

2.6 Summary and Rationale

Is a unitary whole perceived prior to the perception of parts, or are parts processed first and then synthesised to form a whole? This unresolved issue has generated a wealth of empirical research in the psychology of perception. The feature analytic approach has emphasised the role played by local components of a visual object (Treisman, 1986). On the other hand, the global precedence hypothesis has suggested the primacy of wholistic or global processing (e.g., Navon 1977). The global-local relationship seems to be a revival of the earlier concepts in developmental and Gestalt psychology on the issue of part-whole relationships (Antes & Mann, 1984; Pomerantz, 1981). Most visual objects are composed of parts that can be perceived individually. The global precedence effect empirically refers to a situation in which processing of the global level dominates the processing of the local level about the speed or order of processing, or the distinctiveness of the global level in capturing attention. However, the perception of a compound pattern at the subjective level might not coincide with the perception of that stimulus at the functional level. Therefore throughout the present research the concepts global/local advantage and global/local interference are used to refer to empirical findings rather than to theoretical accounts of the wholistic/analytic processing which need more precise empirical support.

Lasaga (1989) argued that because of the effects of conditions such as sparsity, size of visual angle, eccentricity, location of stimulus presentation, goodness of stimulus, and attentional factors, it may be concluded that there is no sequential order in the processing of the global and local levels. However, the majority of those who have proposed the inevitability of global precedence (Navon, 1977) and those who have questioned the generality of that effect (e.g., Hoffman, 1980; Hoffman & Nelson, 1981; Kinchla & Wolfe, 1979; Lamb & Robertson, 1990; Martin, 1979a) have two common concerns: First, the global configuration and local elements correspond to two distinct perceptual levels. Second, it is critical to find out the order of processing of these two levels (Kimchi & Palmer, 1985). Navon (1983) suggested that global precedence is a claim about the order of processing of the global and local features. However, temporal

precedence of one level over the other does not determine if this precedence is simply because of earlier availability of information at that level or if it is the result of using the output of one level to process the information at the level completed later (Lasaga & Hecht, 1991). Studies up to now have not provided strong evidence on the inevitability of the processing of either the global or local level as the necessary input for the processing of the other level.

Exploration of perceptual units of the stimulus is one of the major objectives of the psychology of perception. It is frequently assumed that there are two perceptual levels corresponding directly to the global configuration and local elements. However, it seems that the percepts of global and local levels do not directly correspond to geometrical levels of the stimulus structure (Kimchi & Palmer, 1982). Geometrically global and local levels of the many- and few-element stimuli are perceived differently. Many-element stimuli are perceived as an overall form associated with a texture, whereas both the global and local levels of few-element stimuli are perceived as forms (Kimchi & Goldsmith, 1992). Meanwhile, visual parts of an object do not usually coincide with the elements out of which an object is composed (Klein & Barresi, 1985). For example, the human body is made up of some cylindrical forms, such as the trunk, limbs, neck, and head. However, the body is made up of various chemicals. In the same way, local elements of all compound pattern are not features of global configurations. For example, the features of the compound letter H composed of small Es are horizontal or vertical lines, and not the local components.

Experiments reported by Pomerantz (1981) and Garner (1974, 1978a) suggested that separated, separable, and integral dimensions are perceived differently. It seems that the type of stimulus structure determines if it is possible to attend selectively to one level while ignoring the other. A stimulus with integral dimensions is perceived as a unitary whole. Those varying along separated dimensions are perceived in terms of distinct attributes. It seems that attending to one of the dimensions of integral stimuli is difficult, whereas separated dimensions permit 'selective attention' to any of the dimensions.

Some issues should be highlighted regarding the global precedence hypothesis. First, empirical findings on the temporal precedence of the global configuration do not necessarily mean that the global configuration is salient in the final percept. Second, at least early versions of the global-precedence hypothesis (e.g., Navon, 1977, 1981b) did not differentiate between attentive and preattentive stages of attention. Third, the global precedence hypothesis initially interpreted global advantage and global interference as indicators of the precedence of the processing of the global configuration. Experimental findings such as faster or more accurately processing of the global or local level, interference of the processing of one of the levels with the processing of the other level, resistance of one of the levels to the effects of the processing of other forms, and its resistance to degradation, noisy conditions, and shorter exposure time are empirical findings which might or might not be related to the theoretical account of wholistic/analytic processing. Fourth, global and local levels of all compound patterns do not bear the same relationship. In previous parts of this research four major types of relationships between the global and local levels were distinguished: inclusion, placeholder, featural, and dimensional. It was also suggested that any of these types of relationships may or may not be associated with a semantic relationship between the levels. It appears that a major part of the controversy over the global precedence hypothesis originates from not differentiating between various types of global-local relationships. Different types of stimulus seem to be perceived differently. Therefore, it appears that there is no general answer to the problem of global/local precedence. With the existing level of knowledge on this issue, it seems reasonable to endeavour to extend our empirical knowledge on the global/local advantage and global/local interference of various types of stimuli rather than answering all aspects of the problem of wholistic/analytic processing which is embedded within the theoretical account of the 'global precedence effect'.

A very important question concerning the global precedence effect is if this effect is produced by optical and neural properties (structural mechanism) of the visual system or by cognitive-judgment factors (strategy mechanism). According to the structural

approach, the global precedence effect may reflect processing in the eye and brain, and physiology of eye and brain and physical properties of the stimulus. The sensation source of the global/local advantage may be interpreted as the presence of two distinct and independent channels one of which has higher speed or higher level of activation than the other. The literature on the association of global advantage with spatial frequency channels is an example of this view. In contrast to this interpretation, the strategy approach is tied to cognitive strategies. According to the latter global precedence may be justified by learning, adjustment, expectation, and decision making. Any cognitive component that does not disappear by training would be erroneously coming from a structural source (Coren & Porac, 1984). Physical properties of the global and local levels and their impact on sensation seem to be the preliminary data for global/local processing. Obviously, perception includes cognitive processes and its study cannot be restricted to aspects of sensation. It seems that attention, expectation of the subjects, and other cognitive aspect probably operate within the framework and within the limits provided by physical properties of the stimulus. Therefore, the clarification of the role of physical aspects of the stimulus appears to be an important step in the study of low level perceptual mechanisms in global/local processing.

The main underlying assumption of the global precedence hypothesis is that the global and local levels are equally recognisable, codable, and complex (Kimchi, 1992). Therefore, the difference in the speed of processing of the two levels may be interpreted as a result of either a decrease or an increase in the speed of processing of any of the two levels, or a decrease in processing of one of the levels accompanied by an increase in the processing of the other level or vice versa. Thus, it may be argued that a global advantage is the result of a decrease in the speed of processing of the local level because of visual masking or it is due to a facilitation in favour of the global level (Banks & White, 1984; Breitmeyer, 1984; Murphy & Eriksen, 1987; Podgorny & Shepard, 1983). For example, Williams and Weisstein (1978) suggested that individual lines are discriminated more accurately when they are combined within the context of a global form than when presented alone. There is also the possibility of any asymmetric decrease or increase in the

speed of processing of the two levels when they are presented within the structure of a compound pattern in comparison to the speed of processing of their individual presentations.

Although information processing is mainly determined by the characteristics of the input (Garner, 1970; Sergent, 1983a), the nature of input is sometimes ignored in experiments on perception. Variables such as exposure duration, luminance, retinal eccentricity, and stimulus size all contribute to the efficiency of the visual processing. Potential discriminability of the global and local levels has been mentioned as a source of global advantage and interference. For example Lasaga (1989) stated that the "relatively large differences between local and global levels (e.g., size, eccentricity, sparsity) of Type-D stimuli, which are normally inherent to these levels, can produce information-precedence because of these differences and not because of the difference in level of complexity, *per se*" (p. 173). To the best of this researcher's knowledge, with the exception of Navon and Norman's study, there is not any well controlled investigation of the effect of size on the global/local advantage and interference. However, these workers studied size effect in a size/eccentricity certainty condition and in limited retinal locations. Therefore, results of their study are not generalisable to size/eccentricity certainty conditions and to all eccentricities. Meanwhile Navon and Norman's study was conducted only with stimuli whose global and local levels had placeholder relationships with each other. Therefore, their results are not generalisable to other types of the global-local relationship.

Also it has been reported (e.g., Campbell & Robson, 1968; Shulman, 1987; Shulman, Sullivan, Gish, & Sakoda, 1986; Shulman & Wilson, 1987) that there is a relationship between the sensitivity of retinal locations and the spatial frequency of the stimulus. For example, it is reported that high spatial frequencies are not perceived beyond an eccentricity of 5° (De Valois & De Valois, 1980; Tootell, Silverman, & De Valois, 1981). The overall conclusion which can be made from the existing literature is that the global level may be processed slower than the local level with an increase in eccentricity (e.g., Kawabata, 1990; Pomerantz, 1983). Variations in reaction time to the

identification of a stimulus with changes in eccentricity have been explained using either attentional explanations, i.e., shift of attention and gradient theories (e.g., Eriksen & Yeh, 1985; LaBerge 1983) or by the decrease in the density of cone receptors at the peripheral locations (Yellott, Wandell, & Cornsweet, 1984). There is no agreement in the literature on source of variations in RT across eccentricity. Especially we do not know the effect of the interaction of eccentricity and size on processing of global and local levels of various relationships with each other.

The present research is designed to study the possible effect of size on processing of the global and local levels when the eccentricities of two levels are equated. Meanwhile, the research is targeted at the effects of variations in eccentricity and size/eccentricity certainty versus uncertainty on the global/local advantage and interference. These factors will be studied in relation to the general question on the role of low-level versus high-level processes in the global/local precedence effect. As was mentioned previously this effect may reflect low-level visual factors, or higher level attentional or decision making mechanisms, or a mixture of these factors. The series of experiments carried out in the present research will help to answer this general question within the constraints of my experimental conditions. The research is limited only to compound stimuli with placeholder and inclusion relationship. It seems that interpretation of the effect of cognitive aspects in processing of the global and local levels will be better understood if the roles of size and eccentricity as two major physical properties of the stimulus are clarified.

Chapter 3

Relative Size and the Global/Local Advantage and Interference Effects

Apart from any attributed reality of the "objective" level of the outside world, there has been a strong trend in philosophy, suggesting the "subjective" tendency of human mind to perceive knowledge in terms of wholistic properties (e.g., Engels, 1940; Hegel, 1969; Husserl, 1900/1970; Moore, 1953). The global precedence hypothesis as "the modern version of the Gestaltist claim," (Kimchi, 1992, p. 24) implies that the perceptual primacy of the global configuration is attributed to some type of perceptual or postperceptual preference to perceive the global configuration faster and or before than local components (See, Kimchi, 1990; Kimchi & Merhav, 1991; LaGasse, 1993; Navon, 1977, 1981a, 1983, 1991, Wandmacher & Arend, 1985). The primacy of wholistic properties has been experimentally investigated by using the global precedence paradigm.

Human perception is influenced by the structural redundancy (correlation) of the properties of visual objects (Kinchla, Solis-Macias, & Hoffman, 1983; Hoffman, Nelson, Houck, 1983). Components of a natural scene have usually certain semantic and structural relationships with each other. Individuals' previous familiarity with these relationships and the cues provided by them, creates a serious obstacle to the laboratory study of the relationship between the global and local levels. The global precedence hypothesis (Kinchla, 1974; Navon, 1977) introduced particular type of experimental stimuli in which the identities of the global and local levels do not depend on each other. The main disposition of these stimuli is that their global and local levels do not cue each other. For example, a large letter such as an S may be composed of any letter or non-letter, and the identities of the two levels may be consistent or inconsistent with each other. Therefore, the global and local levels are not necessarily predictable from each other. Because of the possibility of the independent manipulation of the identities of the global configuration and local components, this type of stimulus provides a suitable tool

to test the global precedence hypothesis. However, one of the main difficulties concerning this sort of stimulus is the limited possibility of the manipulation of the relative size of the two levels, without causing a serious distortion in the global configuration and/or a decrease in the discriminability of local components in comparison to the global level. Because of this difficulty, in the present experiment a type of compound pattern was used as the stimulus which the relative size of its global and local levels is easy to be manipulated. The idea behind this study was to examine the effect of relative size of the two levels on the global advantage effect.

Discriminability

If global precedence is found in a condition in which the global dimension is more discriminable than the local elements, the effect may be attributed to the difference in the discriminabilities of two dimensions. Therefore, one of the earliest presumptions in the study of the global precedence effect was that the global and local levels are equally recognisable (Kimchi, 1992). Discriminability is reported to be related to physical properties of the stimulus, such as relative size, eccentricity, density, continuity and discontinuity of contours, degradation, stimulus duration, and luminance (Estes & Wessel, 1966; Sargent, 1983a). As Garner (1970) suggested the nature of input is usually ignored in the experiments of the perception. However, there are still few studies on the role of physical aspects of the stimulus on the processing of the global and local levels. The difference in sizes of the global and local levels of a compound pattern may affect their discriminabilities. Findings indicating that the presence or absence of the global advantage may depend on perceptual factors effecting the quality of information available at the global and local levels (e.g., Kinchla & Wolfe, 1979; Martin, 1979a; Miller, 1981; Navon & Norman, 1983; Pomerantz, 1983; Pomerantz and Sager, 1975; Pomerantz, Sager, & Stoeber, 1977), support the view that the difference in response times and the accuracy rates to the global and local levels may originate from the variation in the discriminabilities of the two levels. Some workers (e.g., Boer & Keuss, 1982; Garner,

1978b; Pomerantz, 1981) suggested that if the relative discriminabilities of the global and local levels are matched, local elements may be processed faster than global properties.

On the other hand, Kimchi (1992) suggested evidence inconsistent with discriminability as a full account of the global advantage. From equal reaction times to the global and local levels when either of the global or local levels was presented individually, Hughes, Layton, Baird, and Lester (1984) concluded that there was not any difference between discriminabilities of the global and local levels. Workers such as Wandmacher and Arend (1985) proposed that under normal viewing conditions postperceptual and attentional mechanisms and not the difference in discriminabilities of the global and local levels fit best with the precedence in the selection and utilisation of the global configuration to the local components. However, it seems that global and local levels have some inherent physical differences which may affect the perception of the two levels. Perhaps the most distinct aspect in discriminabilities of the global and local levels is the difference in the size of the two levels.

Size

The results reported by Navon (1977) on what he called 'global-to-local' order of processing were based on the earlier and/or faster availability of the global information of hierarchical patterns. In this early work Navon's argument was in line with the postulate of Gestalt psychology that there is a preference in the perceptual organisation to process the whole rather than the parts. That is perceptual organisation precedes from the global information to the local information over time. Kinchla and Wolfe (1979) rejected the generality of 'global-to-local' processing. They argued that the order of processing of the global before local level is not always inevitable but changes according to the visual angle of the stimulus. Kinchla and Wolfe suggested that an increase in the visual angle of a compound shape beyond 6°-9° changes the temporal order of processing in favour of the local figures. Using line drawings of natural scenes, Antes and Mann (1984) obtained results similar to Kinchla and Wolfe's findings. They demonstrated that the global level was identified faster than the local level when the visual angle of the stimulus was small

(4°), but local elements were processed more quickly when the visual angle of the global target was large (either 8° or 16°).

Navon and Norman (1983, Experiment 1) argued that Kinchla and Wolfe confounded globality and eccentricity. According to these workers, when the size of the target stimulus was enlarged the global figure was displayed at a more peripheral location than some of the local letters; therefore, the latter figures benefited from better acuity. Thus if the eccentricities of the global and local levels were equated, the global level would be responded faster than the local level, regardless of the visual angle of the stimulus. To avoid confounding eccentricity and globality, the local elements of the stimuli they used were located along the perimeters of the global stimuli. That is both global and local levels were displayed at the same retinal location and, therefore, had the same eccentricity. There were two visual angle size conditions, 2° and 17.25°. One of these visual angle conditions was above and the other was below the point the speed of processing of the global level was preceded by the speed of processing of the local level, as suggested by Kinchla and Wolfe (1979). The results of Navon and Norman's study demonstrated a global-to-local order of processing both for the small and large visual angle conditions. Therefore, Navon and Norman (1983) argued that when the confound of eccentricity was avoided, the global level is processed faster than the local level. Meanwhile, the results from the control condition of that experiment demonstrated a non-significant difference between the reaction times to local figures presented either as the elements of the global patterns or as a single figure displayed at the highest location of the global stimulus. From this result, Navon and Norman (1983) concluded that if the eccentricities of the global and local levels are equalised, only size will be the determinant of the global precedence effect.

Even if all aspects of the discriminability of the global and local figures such as, eccentricity, density, continuity, luminance, and goodness of the shape, are equated, it seems impossible to equalise the sizes of the global and local levels of a compound pattern. A local component is by definition a part of the global configuration and therefore, it is smaller than the whole figure. However, the information about the

importance of size in the global precedence may be obtained by studying the effect of variations in the relative size (ratio of sizes) of the global and local levels on the processing of any of the two levels. This technique was initially used by Kimchi and Palmer (1982) in similarity judgment and verbal description tasks. In that experiment the number of local elements of compound patterns and their sizes relative to the global configuration were varied in a set of five experiments. The results demonstrated that patterns composed of many relatively small elements were perceived as overall forms associated with a texture, whereas both the global and local levels of patterns consisted of few relatively large elements were processed as forms. Kimchi and her associates (Kimchi, 1983, 1988, 1990; Kimchi & Merhav, 1991; Kimchi & Palmer, 1985) studied the perceived organisation of hierarchically constructed pattern, however they did not examine the effect of variations in size of local elements in the global advantage and asymmetric interference of the two levels. To the best knowledge of the writer of the present research the only exception in which RTs to the many- and few-element stimuli were determined was Kimchi and Merhav's (1991) study. However, that study was conducted to test hemispheric processing of global and local levels. The main thrust of the present study is to test the effect of variations in the size of the local level while holding the size of the global configuration constant, on the temporal order of processing and interference-facilitation of the two levels on each other. Meanwhile, the present study provided an opportunity to study the possible role of hemispheric specialisation on the processing of the global and local levels of a compound pattern. The following section discusses these issues.

The Global Precedence Effect and Hemispheric Asymmetry

Some workers have suggested that the right hemisphere is involved global functioning, and the left hemisphere is associated with the analysis of separate properties and features (See, Lamb, Robertson, & Knight 1989; Robertson & Lamb, 1991; Treisman, 1986). This view of the differentiation of the cerebral hemispheres began with the observation that damage to the left hemisphere was associated with a disruption in the

perception of parts while a right hemisphere lesion was accompanied by a poor response to global configurations (Robertson & Lamb, 1991; Treisman, 1986). For example, it was demonstrated that if patients with left hemisphere lesions were asked to draw a figure similar to the stimulus used by Navon (1977) from memory, they were more likely to miss local letters, whereas when individuals with right hemisphere lesions were required to perform the same task, they tended to miss global configuration (Robertson, & Lamb, 1991). Thus there is a suggestion that the right cerebral hemisphere is involved with the generation of wholistic descriptions and their recognition and the left cerebral hemisphere is involved with the analysis of the whole into parts and the perception of parts. This asymmetry has led to a theory of hemispheric functioning according to which the left and the right hemispheres respectively operate analytically and wholistically.

Meanwhile, the presence of asymmetric interference in normal subjects and lack of interference in patients with left or right hemispheric lesion has been interpreted as a sign of automatic directing of attention to the global level in normal individuals (Robertson & Lamb, 1991). As was mentioned in the previous chapter, global/local interference in the context of the present study refers to the asymmetric facilitation and/or interference caused by the identity of the unattended either global or local level on the response time to the attended level in a Stroop-type task. This mechanism is reported (Robertson & Lamb, 1991) to be absent in patients with a right hemisphere lesion. Meanwhile, from the data that the global information is available earlier to patients with lesions in the left hemisphere and local information is more easily accessible to patients with lesions in the right hemisphere, Robertson & Lamb concluded that the processing of these two levels is independent from each other. Therefore, the interference between the two levels cannot originate from the availability of these asymmetrically presented analyses. According to these workers, the interaction belongs to a mechanism independent of global or local advantage. Therefore, damage to either of the hemispheres eliminated interaction between the global and local levels. It has been suggested (e.g., Humphreys & Riddoch, 1987; Milner, 1971) that this interaction is possibly organised by the inferior bilateral prestriate region. Generally speaking, it may be suggested that the information processed by the

hemispheres of the normal brain strongly interact to analyse hierarchical relations between stimuli.

On the other hand, there are some other workers who report different results. Kimchi and Merhav (1991) conducted a study with many- and few-element stimuli to test the effect of stimulus-type, relative size, and number of elements on hemispheric specialisation. The assumption underlying their study was that if the major functional difference between the hemispheres resides in the difference in processing different spatial frequencies, hemispheric asymmetry between the global and local levels of many element stimuli will be more pronounced than few element stimuli because there is less overlap in spatial frequencies between the global and local levels of many-element patterns, due to the relative size of their elements. The results of their study (Experiment 1) indicated a left hemisphere advantage for the local level and a right hemisphere advantage for the global level when stimuli were processed in terms of the global or local level. However, when subjects were instructed to attend either to the global form or texture, no hemispheric difference was obtained (Experiment 2). Kimchi and Merhav attributed the difference in the results of these two experiments to the distribution of attention in the second experiment in contrast to 'focused attention' in Experiment 1. However, the difference in pattern of responses of these two experiments may originate from the difference in the type of stimuli used in them. There are some other reports that right and left visual field advantages are influenced by the retinal location of the stimulus (e.g., Kinsbourne, 1972). For example, a right visual field advantage was suggested (Sergent, 1983a) for pairs of letters when they were projected to an eccentricity of 2.5° while a left visual field advantage was reported when the same stimulus was projected to eccentricity of 11° . Switch between the two visual fields was not found below 4° (Sergent, 1983b).

There is still much to be studied and explored about hemispheric specialisation and the processing of the structural levels of the compound patterns, especially with non-letter stimuli. This becomes more important when considered in terms of the importance of relative size as the major determinant of the global precedence effect. In fact, if the reaction times to the global and local levels are not affected by the hierarchical structure of

the stimulus, and size is considered as the determinant of the global advantage, hemispheric differentiation will possibly be explained only by the sensitivity of hemispheres to different ranges of spatial frequency channels. One of the thrusts of the present study is to examine the role of hemispheric specialisation with regard to variations in the relative size of the global and local levels of non-letter stimuli.

3.1 Experiment 1

Although in Navon and Norman's (1983, Experiment 1) study the size of stimulus was manipulated, the relative size of the local and global levels was held constant. That is in both large and small visual angle conditions the ratios of the sizes of the global and local stimuli were 8.5 to 1. Therefore, it may be argued that if the relative size of the two levels in that experiment was changed, the latency pattern would vary (Kimchi & Merhav, 1991). Meanwhile, Navon and Norman used central stimuli; i.e., the stimuli in their experiment laid round the fixation point; that do not necessarily predict the pattern of results when all stimulus properties are displayed either to the right or to the left of the fixation point. On the other hand, if Navon and Norman were right in their suggestion that the difference in sizes of global and local images is the prime determinant of global advantage, a change in the relative size of global and local stimuli should affect the response latencies and interferences between the two levels. Therefore, it seems reasonable to expect that as the sizes of the global and local levels are made more similar, the difference in the speed of processing of the global and local levels will decrease. In other words, if the faster identification and/or interference of the global level are produced by the difference in sizes of global and local levels, increasing the size of local components, while holding the size of the global configuration constant, may result in an increase in the speed of the identification of the local shapes. Therefore, it is important to test the variations in the global/local advantage when the relative size of the global and local levels is manipulated. To examine these effects, subjects were presented with large horizontal or vertical lines composed of small horizontal or vertical lines (Figure 8).

Although the sizes of global figures were held constant, sizes of the local elements varied between trials by the ratio of 1:2:3.

If global precedence is found only in the randomised experimental presentation ('divided attention') condition, it may be interpreted as the failure to concentrate attention on the local level rather than any sensory mechanism. However if global precedence is obtained in the blocked experimental presentation ('selective attention') condition, it may indicate that some sensory components are involved (Navon & Norman, 1983). To avoid the possible effect of preferential division of attention between the global and local levels, a blocked presentation condition was dictated in the present experiment. As was mentioned in the previous chapter, the blocked experimental presentation refers to an experimental condition in which global and local target levels were blocked separately. In one block subjects were required to respond to the global level and in the other to the local level.

The fact that a Stroop-type effect is inevitable even when the attention is allocated to only one of the stimulus levels, suggests that selective visual attention is impossible (Treisman, 1986). Therefore, throughout the present research the terms blocked and randomised experimental conditions are used instead of the 'selective and divided attention' conditions, respectively. The former concepts refer to the experimental condition rather than the selectiveness of the attention that does not fit with Stroop-type interference.

Method

Subjects

Twenty-four right-handed first year psychology students at the University of Wollongong served as subjects. They all reported normal or corrected to-normal vision. They received course credit in return for their participation in this experiment. Each subject participated in one experimental session of approximately 30 to 40 minutes duration.

Apparatus and Stimuli

Stimulus patterns were displayed on a VGA monitor and the experiment was controlled by an IBM compatible computer. The RT resolution of the software was 1 msec, and the refreshment rate was about 16 msec. In this thesis the refreshment rate refers to the time required for a frame to be flashed on the screen. The monitor had a matrix size of 640 x 480 pixels. Each pixel was associated with an image 0.37 mm in length and 0.39 mm in width on the monitor. The stimuli were made of a number of pixels per element. The experiment was conducted in a darkened room. All stimulus events were white on a black background, giving a very high contrast. The luminances measured by a TEKTRONIX J6526 1° Narrow Angle Luminance Probe, was approximately 2 cd/m². All viewing was binocular. The subjects viewed the display at a distance of 80 cm while leaning on a chin rest and resting the index fingers of the two hands on two response keys of a computer key board. The stimuli were large either horizontal or vertical lines made up of small either vertical or horizontal lines (Figure 8). The stimuli were made by allocation of appropriate number of pixels per element. There

Figure 8. A sample of stimuli used in Experiment 1.

were four types of stimuli: a horizontal configuration made up of small horizontal lines, a horizontal configuration made up of small vertical lines, a vertical configuration made up of small vertical lines, and a vertical configuration made up of horizontal lines. Therefore, the global and local aspects of stimuli were either consistent (both horizontal or both vertical) or inconsistent with each other (one level vertical and the other level horizontal).

The visual angles of the length and width or height and width of the horizontal and vertical global configuration were approximately 7° and 2.6° , respectively.

The size of the large configuration was constant, but the local components were presented in three size patterns (type A, B, or C). This was done by connecting either two or three local line segments to each other while either doubling or tripling the spacing among the elements. The visual angle of the type A, B, and C local horizontal or vertical lines were 0.3° , 0.6° , and 0.9° , respectively. That is the length of the local elements of type A was half of the type B, and one third of the type C local components. The probabilities of the presentation of stimuli composed of either of the local sizes were equal. The stimuli were presented with their centres 4.5° of visual angle either to the right or to the left of the fixation point, measuring a visual angle of about 0.05 degree. The contrast and luminance of the fixation stimulus was the same as other stimulus events. The total lengths of local lines in all stimulus types were equal. In other words, when the local lines became longer the space between them increased, and when they became smaller the space between them decreased and they became less sparse than the other condition. Therefore the total amount of light intensity produced by each global configuration was reasonably constant.

Mask stimulus: All the experiments reported in this thesis were conducted in a darkened room. To control the potential confound of afterimage each trial was followed by a mask stimulus. The mask stimulus was randomly located white line segments (slashes and back slashes) of approximately 3.2 mm long on a black background, giving a very high contrast. The luminance of the mask stimulus was approximately 2 cd/m². The same mask was used in all experiments and in each trial. They were about 30 degrees either oblique to the right or to left. The average distance of the centre of each element from the centres of adjacent elements in the right, left, above, and below was about 5.00 mm. In fact, the mask stimulus was a full screen of randomly located slashes and backslashes. Since viewing distance was 80 cm in Experiments 1, size of each mask

element in visual angle was 0.23 degree. The average distance of the centre of each mask element from the centres of adjacent elements was about 0.36 degree.

Design and Procedure

The experiment was conducted individually in a single session. Subjects were instructed that each trial would start with the presentation of the fixation stimulus. They were required to fixate the middle of the screen where the fixation stimulus was displayed. After each of the practice and experimental blocks the subjects were reminded to fixate at the fixation point during the experiment. The stimuli were presented randomly either to the right or to the left visual field while subjects fixated on the fixation point. Every experimental session consisted of eight blocks. The first two blocks were warm-up blocks that were not included in the analysis. One of the practice blocks was targeted to the global shapes and the other was allocated to the recognition of the local figures. The order of the six experimental blocks was randomly designed either as global or local. There were 16 trials in each practice block. At the beginning of each experimental block, subjects were advised to respond to the global or local level. Each experimental block consisted of 64 trials which were arranged randomly from the 12 possible patterns. Each trial was initiated by the onset of a plus sign in the centre of the screen. It was displayed for 1000 msec before the display of the experimental stimulus and remained on the screen with it. The subjects were required to fixate on that mark before and during the exposure of the stimulus. The stimulus was displayed for 16 msec, and it was replaced by the mask stimulus. The mask was displayed for the maximum of 2000 msec. Half of the subjects were advised to press a specially marked key with the right index finger if the target shape was a horizontal line, and another specially marked key with the left index finger if the target was a vertical line. Hand/key assignment was reversed for the other half of the subjects. Subjects had 2000 msec to respond to the stimulus. Immediately after pressing one of the response keys the mask disappeared. Only incorrect responses were followed by auditory feedback. Subsequent trials started 1000 msec after a response or after the

time-out of the mask. Reaction times and accuracies were recorded for each trial. The subjects were instructed to respond fast but to avoid errors.

Results

The main results are demonstrated in Figure 9, in which mean response times for the global and local levels are indicated by black and hatched bars, respectively. A within subject analysis of variance (ANOVA) was performed on the reaction times¹. The factors were: target level (global or local), size of the local elements (types A, B, and C), consistency (consistent or inconsistent), visual field (right or left), identity of the global level (horizontal or vertical), identity of the local level (horizontal versus vertical), and response key (right or left). The data entered into the analysis and graphed were derived from means of the subject's means. Six out of seven main effects were significant. Consistent with earlier findings (Boles, 1984; Lasaga & Hecht, 1991; Luna, Merino, & Marcos-Ruiz, 1990; Navon, 1977, 1983, 1991) the global level was identified faster than the local level, $F(1, 23) = 324.86$, $p < 0.0001$. The comparison of the reaction times to the target levels in three size conditions revealed that there was not a significant difference in the reaction times to the global level with the variation in the sizes of the local elements. However, RTs to the identification of the local level decreased significantly with the increase in their size (Figure 9), $F(2, 46) = 10.95$, $p < 0.0001$. This pattern is reflected in the significant interaction between target level and size, $F(2, 46) = 16.71$, $p < 0.0001$. Meanwhile, the difference in RTs to the type A and B, $F(1, 23) = 43.65$, $p < 0.0001$; type B and C, $F(1, 23) = 9.74$, $p < 0.0048$; and type A and C, $F(1, 23) = 92.76$, $p < 0.0001$; were significantly different.

¹ In all the experiments of this thesis trials on which responses were in error were omitted prior to analyses. Also, in all the experiments throughout this thesis data were initially analysed based on both medians and means. The patterns of results based on analyses of medians were similar to the results based on analyses of means. Since the results of the two analyses were compatible, only the results of analyses based on means are reported here.

The consistency of the two levels influenced the response times. Both global and local levels were identified faster in the consistent than inconsistent condition, $F(1, 23) = 35.13$, $p < 0.0001$. However, this effect was asymmetric. The average difference in RTs between the consistent and inconsistent levels was about 6 msec for the global level and 24 msec for the local level. This difference was reflected by the significant interaction of target level and consistency, $F(1, 23) = 4.39$, $p < 0.0454$. Further examination of the

Figure 9. Mean RTs as a function of target level and relative size in Experiment 1.

pattern of RTs across target level and local size suggested that the extent of interference/facilitation caused on the global level by the local figures may be related to the size of the local level (Figure 10). It seems that small local elements had little or no interference/facilitation on the perception of the global configurations. The global level made up of local figures of a medium size were identified faster than two other conditions when the global and local levels were consistent. However, when the two levels were inconsistent, the global level of medium size was detected considerable slower than the

other two conditions. This is illustrated in almost equal reaction times to the global configurations made up of consistent or inconsistent type A locals, a significant difference in the response times to the consistent and inconsistent global figures made up of type B, $F(1, 23) = 10.39, p < 0.0038$; and a considerable but not significant difference between

Figure 10. Mean RTs as a function of target level, relative size, and consistency in Experiment 1.

the consistent and inconsistent global configurations composed of type C locals.

There was a strong effect of the superiority of left visual field (Figure 11) in the processing of both global and local levels, $F(1, 23) = 41.32, p < 0.0001$. This primacy did not change across other variables such as size of the local level, the consistency of the levels, and the identity of the target level. The main effects of identity of the global level, $F(1, 23) = 13.88, p < 0.0009$; and identity of the local level, $F(1, 23) = 4.43, p < 0.0444$; interaction between the target level and the identity of the global level, $F(1, 23) = 19.95, p < 0.0001$; and interaction between the size and identity of the local level, $F(2, 46) = 7.64, p < 0.0012$, were significant. These interactions reflect the fact that horizontal global

configurations facilitated the processing of the local figures. However, there were not any significant differences in the response times to the identification of the global level, according to its identity. Meanwhile, the response times to both structural levels were faster when the local elements were horizontal than vertical.

To study the effect of the interference of the unattended global level on the identification of the attended local level according to the visual fields, the differences in the average reaction times to the attended local levels in the consistent and inconstant pairs

Figure 11. Mean reaction times as a function of target level and visual field in Experiment 1.

were compared by a ttest procedure. The average difference between the reaction times to the inconsistent and consistent condition was 28 msec for the right visual field and 20 msec for the left visual field. The difference between the averages was significantly different [$t(23) = 2.09, p < 0.05$]. The same procedure was conducted for the global level displayed in the right and left visual fields. The mean difference between conditions were calculated separately by subject and by visual field. Then, the average facilitation-

interference was 1 msec for the right visual field and 11 msec for the left visual field. The average difference between mean differences was not significant but interference produced by unattended local level on the attended global level was considerably stronger in the left visual field than the right visual field, $t(23) = 1.48$, $p < 0.16$. These results suggest that the extent of the effect of the global configuration on the local element was stronger in the right visual field (left hemisphere), whereas the influence of the identity of the local on the global level was stronger in the left visual field (right hemisphere). These results cannot be interpreted by speed-accuracy trade-offs. That is the local level was less vulnerable to interference from the identity of the global level in the right hemisphere than in the left. In contrast, the global configuration was less affected by the identity of the local level in the left hemisphere than in the right. The comparison of the variation in the state of the susceptibility of any of the two levels regarding the identity of the other level, with the pattern of RTs across the visual fields, suggests that the patterns of response times to the global and local levels and the pattern of global/local interference are probably regulated by different hemispheric mechanisms.

Reaction time is usually used as independent variable in the studies on visual perception. In a RT task subjects are usually required to respond as rapidly and as correctly as possible. Luce (1986) pointed out that in this type of experiment, the task is performed at a point on the speed-accuracy trade-off function where small variations in error rates, such as 1%- 2%, may be associated with large shifts in RTs. Therefore, it seems necessary to trace out speed/accuracy functions especially when their trends are contradictory. That is when the faster processing is associated with higher error rate. As a result, in the present study a similar analysis to RT study was conducted on accuracy levels. The factors and levels were the same as for the latency analysis. The results indicated no significant main effects except for the visual field, $F(1, 23) = 4.64$, $p < 0.0364$. Subjects tended to make more accurate response where stimuli were presented in the left visual field than the right visual field. There were no other significant effects of interest in RT and the rate of accuracy analyses (Tables 3 & 4). Mean reaction times and accuracy proportions to the various combinations of the size of the local figures,

consistency, and target level are displayed in Table 1 & 2 (Appendix A). The comparison of latency and accuracy data indicated that none of the latency analysis could be attributed to a speed-accuracy trade-off.

General Discussion

In the present study the size of the local components was changed by the proportions of 1, 2, and 3. As a result the relative size (proportion of sizes) of the global and local levels and the spacing between them varied with the same rates. The results indicated global advantage in a condition that the test stimulus was followed by a mask stimulus. The global advantage has been reported in many experiments (e.g., Navon, 1977) that have been conducted in a condition where no mask stimulus was employed. Therefore, it seems that masking cannot account for the global advantage effect found in this experiment, although it might have some effects on global advantage and interference effects. In the next chapter it will be explained that masking cannot be also account for the results on the effect of size. In contrast, masking seems to be a very useful procedure concerning the control of the confound of afterimage. Afterimage can be a serious confound specially when experiment is conducted in a darkened room, the condition was used in this experiment.

The results of this experiment showed not only the determinant role of size in the peripheral presentation of the stimulus, but also suggested that the difference in the global advantage and asymmetric interferences of the global and local levels depends on the extent of the difference in sizes of the global and local levels. An increase in the size of the local level decreased the response times to the local level, but did not affect the overall reaction times to the global level. This disparity in the effect of variations in size of the local level on the reaction times to the global and local levels suggests that the processing times to the global and local levels were mainly determined by sizes of the two levels, when the reaction times were not differentiated according to the consistency or inconsistency of the two levels. Meanwhile, the results showed that both global and local

levels interfered with the perception of the other level. The magnitude of the interference was influenced by the relative size (the ratio of sizes) of the two levels.

On the other hand, an increase in the size of the local components was accompanied by a proportional increase in the spacing between them. That is larger local components were separated from each other with a wider space. Spacing was not considered as a variable in this study, but since it was proportionally related with variations in size of local components, the former variable was indirectly measured in this experiment. In fact, variable of size can be used as the index of variations of density/sparsity. The results indicated that the increase in sparsity was not associated with significant changes in reaction times to the global level. Meanwhile, the increase in sparsity was not accompanied by a linear increase in interference. There was no significant local interference in the densest condition. The extent of local interference was the highest in the medium density condition. Further increase in sparsity decreased the magnitude of local interference. The inconsistency of the results of the present experiment and those in the density/sparsity literature (e.g., Lovegrove & Pepper, 1994; Martin, 1979a) may arise from the difference in the number and size of stimuli used in the present experiment and previous studies. As was mentioned already with an increase in size of local components the space between them was increased, but the total length of local components within each global configuration which can be expressed in terms of luminance flux remained constant. As a result, total magnitude of light-output of each compound pattern was almost constant. Perhaps, the discontinuity of the results of the present experiment and density/sparsity literature originates from the fact that in majority of those studies sizes of the local components were held constant therefore, increase in sparsity was associated with a decrease in the total magnitude of light-output of the compound pattern. Thus, it may be speculated that at least part of the effect reported by density/sparsity literature may be related to variations in energy of light received by the subject.

There are many studies about the effect of similarity and consistency of the global and local levels on the perception of the global and local levels (See, Luna, Merino, & Marcos-Ruiz, 1990). Hughes (1988) suggested that response competition has its origin in

global advantage rather than being its source. On the other hand, Lamb and Robertson (1988) and Lovegrove and pepper (1994) proposed that interference effect and speed of processing of global and local levels may be related to separate mechanisms. The present experiment did not provide enough information about the pattern of interference according to the variations in the relative size of the global and local levels. The results indicated that the reaction times to the identification of the local level in both consistent and inconsistent conditions decreased with an increase in the size of the local level. However, the variation in relative size did not have a continuous effect on the global level. The local figures of the smallest size did not show any interference on the perception of the global level. Thus, it seems that they simply behaved as place holders. The medium size local level generated the highest amount of interference on the perception of the global size. Therefore, the results suggested the possibility of the existence of an optimum relative size in which the local level produces the largest amount of interference on the global configuration.

In the present study a strong left visual field (right) hemisphere advantage was found for the response times to both global and local levels. This advantage did not change with variation in size of the local level or with consistency/inconsistency of the target levels. However, the extent of interference of the global level on the processing of the local level, which was measured by the difference in RTs to the local levels in consistent and inconsistent conditions, was considerably higher in the right visual field (left hemisphere) than in the left visual field. Conversely the magnitude of the influence of the local level on the global configuration was higher in the left visual field (right hemisphere) than the right visual field. That means RTs to the local properties were more vulnerable to the variations in the identity of the global level in the left hemisphere than the right, whereas RTs to the global level were more vulnerable to the variations in the identity of the local level in the right hemisphere than in the left one. In other words, the processing of the local level is less influenced by the identity of the global level in the right hemisphere but, the processing of the global level is less affected by the identity of the local level in the left hemisphere. This data suggested the possibility that the non-letter local figures are less distracted in the right hemisphere and the non-letter global

configurations are less distracted in the left hemisphere. Therefore, it can be suggested that within the limits of conditions applied in Experiment 1 the global/local interference and interference effects were controlled by separate hemispheric mechanisms (Lamb & Robertson, 1988).

Hemispheric specialisation has been explained via two common dichotomies: the verbal/visuospatial dichotomy which proposes that the two hemispheres are specialised differentially according to verbal versus visual tasks; and analytic/wholistic dichotomy which implies a type of specialisation between the hemispheres according to parts and whole relationship. There is a suggestion that the left hemisphere is associated with the processing of local forms and right with the global (Martin, 1979b; Robertson & Lamb, 1991). In other words, local processing in the left hemisphere is more efficient than the right hemisphere, and global processing is more efficient in the right hemisphere than in the left. Lamb, Robertson, and Knight (1989) suggested that interference between the global and local levels occurs as the result of a neural mechanism centred in the posterior superior temporal plane and the adjacent caudal inferior parietal lobe. However, similar to the findings of the present experiment the results of an experiment by Kimchi and Merhav (1991) failed to show a reliable hemispheric difference for many-element patterns when the levels were processed in terms of the global form and texture. Also Alivisatos and Wilding (1982) and Boles (1984) did not find any asymmetry in RTs in cerebral functioning regarding the global and local processing.

The existing contrast between the results of Experiment 1 and Robertson and Lamb's (1991) study and controversy in the literature suggests that the association between hemispheric specialisation and global/local processing indicates that the association made between structural levels of compound patterns and differences in hemispheric processing for the most part is premature. Generalisation of such an association needs a study in which eye movements and handedness are controlled, where there is clear knowledge about the position of features of the stimulus subjects use to identify the target. Otherwise not controlling these factors should be considered a serious confound regarding the generalisation of findings. To the best knowledge of mine there is

not such a well-controlled experiment in the literature. Examination of hemispheric superiority and global/local processing is not the main theme of this thesis. However, I will follow up this relationship throughout my next experiments to study the generalisability of the findings reported in Experiment 1.

If relative size is the prime determinant of the global advantage effect, as was suggested in the present experiment and Navon and Norman's (1983) study, the effect of this determinant can not be easily explained by hemispheric specialisation. Faster reaction times to both global and local levels displayed in the left visual field in comparison to the right visual field in the present experiment, is also in contrast to the literature on hemispheric specialisation of spatial frequency channels. If hemispheres are differentiated according to the spatial frequency channels of the stimulus, global and local levels of a compound pattern have to be responded to by different hemispheres. The results of the present study showed that hemispheres are not probably specialised according to the speed of processing of the global and local levels. Conversely the results of this experiment seem to fit better with the verbal/visuospatial dichotomy of hemispheric specialisation than part/whole dichotomy (See Chapter 2 of this thesis). That is both global and local levels as visuospatial stimuli were preferred by the right hemisphere than the left one. Generally speaking, there may be several reasons for the inconsistency of the data of the present experiment and that of the other studies. First, the stimuli in this experiment were non-letters in contrast to the study of Robertson and Lamb (1991), and Martin (1979a) which letters were used as the stimuli. Second, the stimuli of the present study were projected to more eccentric location than the previous studies. Third, in comparison to some previous studies (Boles, 1984; Martin, 1979a) the exposure duration of the stimuli in the present study was very short, 16 msec. Any or all of these factors might be involved in shaping the pattern of responses of the present study with regard to hemispheric superiority. As was raised in Chapter 2 these factors (i.e., eye movements, stimulus type, spatial location of the stimulus, and exposure duration) may affect hemispheric specialisation and global/local interference. Therefore, inconsistency in the

results of the present experiment and some other studies reported in previously may originate from the difference in the control of the above mentioned factors.

The rationale behind a large number of studies in the global precedence paradigm is that the global configuration and local components of a hierarchical pattern are equally complex, recognisable, and codable (Kimchi, 1992). As was reported in Chapter 2 some studies have questioned equal recognisability of the global and local levels. Absolute size of the target level (Kinchla & Wolfe, 1979; Antes & Mann, 1984) or the relative size of the two levels (Navon & Norman, 1983) has been suggested as the prime determinants of the global advantage effect. However, in both studies the relative size of the global and local levels was held constant. If the relative size is the prime determinant of the global/local advantage and interference effects, its manipulation may influence these effects. The results of the present experiment indicated that the judgment about global properties of a form is easier than the local properties, and the global configuration is more difficult to ignore than the local component. Meanwhile, the results showed that the relative size is probably the prime determinant of global advantage and/or interference when the stimulus is displayed at a peripheral location.

Chapter 4

Source and Locus of Global Advantage

Studies on the global precedence effect began with a desire to discover the relationship between parts and whole. Navon (1977) proposed the idea of the precedence of global configurations over their local constituents. Large letters made up of small letters were used as the stimuli in that study. Kinchla and Wolfe (1979) suggested that temporal order of processing is not always global to local. Rather it varies according to the size of the compound pattern. According to these workers when the stimulus subtended more than 6°-9° visual angle, the global configuration was responded to more slowly than the local elements whereas below 6° the speed of processing of the global level was faster than local components. In their experiments, five visual angles were used, with equal probability of occurrence for each size. The height of the large letters subtended 4.8, 6.7, 8.0, 10.3, 22.1 degrees. The visual angles for the small letters were not mentioned, but since the large letters were composed of 7 small letters in height, the visual angles of the component letters should have been about 0.6°, 0.8°, 1.0°, 1.3°, and 2.8°, respectively.

Navon and Norman (1983) noted that Kinchla and Wolfe (1979) confounded globality and eccentricity. Defending the generality and mediating mechanisms reflected in the global precedence hypothesis, Navon and Norman suggested that as a subject gets closer to a stimulus or as an object becomes larger, the constituents of the stimulus that yield information about the global structure are projected on the peripheral parts of the visual field where the resolution is poor or where there is the possibility of the projection of stimuli beyond the boundaries of the visual field. Thus, magnification of stimuli in a condition where eccentricity and size were confounded may have led to the situation where any processing speed advantage associated with increased size may have been

negated by the effects of eccentricity. However, if the eccentricities of the two levels are equated, the global level will be identified faster than the local component, simply because the former figure is larger than the latter one. Using a paradigm akin to that of Kinchla and Wolfe (1979), Navon and Norman (1983) conducted an experiment using stimuli with all their elements located around their perimeter (e.g., circles or Cs). They asked this question: Are global features located at a certain degree of visual angle eccentricity, processed faster than local features located at the same eccentricity? Eccentricity by definition is the visual angle projected by the distance between any stimulus property and the centre of the visual field. Since the stimuli used in this study were symmetrical, the visual angle of the stimuli was twice as large as the eccentricity.

It should be clarified that in the terminology of Navon and Norman the concept of relative size refers to the difference in sizes of a global property and any of its component parts. They proposed that reaction times for the identification of the local and global features were not related to the structural dependency of the two levels (being a property of a hierarchical structure).

In the control condition of their Experiment 1, Navon and Norman (1983) measured the response time to the identification of the direction of the opening of a single C in the highest location of the global configuration. Nonsignificant differences for RTs to the small letters in the control and experimental conditions ruled out the possible effect of masking which may increase the reaction time to any local properties by the other neighbouring elements. This effect has been suggested in some studies (e.g., Gilden, MacDonald, & Lasaga, 1988; Johnson, 1986; Pomerantz, 1981; Wenderoth & Beh, 1977). For example, Johnson (1986) proposed that his subjects were able to recognise the presence or absence of a letter faster when that letter or a nontarget letter (e.g., B or L) was presented individually than in a condition in which a redundant (repeated) display of them was presented (e.g., BBBB or LLLL). Johnson's interpretation of this single-letter advantage was that when letters were located close to each other they interfered with the processing of one another. In fact, based on the Navon and Norman's study it may be claimed that slower reaction times to the local letters are not due to the masking effect on

the local elements, or because of being a lower-level property in a hierarchical structure, or any kind of facilitation in processing in favour of the global configuration, but it is the result of the relatively small size of the local elements in comparison to the global configurations. In other words, in terms of Navon and Norman's argument, it is unlikely that the global advantage was related to the structural dependency of the two levels, relative salience of the global configuration, or any sort of masking effect on local components.

Controversy in the Literature

The results obtained by Navon and Norman (1983), however, were not fully compatible with their argument. The subjects' response time on global stimuli as small as the local components of the compound stimuli in the large condition (2.00°) were the same as their performance on the global level of the large condition with visual angle of 17.25° rather than the local elements of that condition with a visual angle of 2.00° . Therefore, it may be asked why if size was the prime determinant of globality, the reaction times to the global configuration with a visual angle of 17.25° were the same as the RTs to the global stimulus of the visual angle 2.00° . Anticipating this possible question, Navon and Norman (1983) speculated that the effect of "eccentricity may often counteract that of size" (P. 961). However, Navon and Norman (1983) did not study the role of eccentricity which may have worked in the opposite direction to the effect of size. Therefore, even if their explanation of the relationship between retinal image size and the global temporal dominance was correct, their study did not clarify the possible effect of eccentricity and the interaction of eccentricity and size effects on the processing of global and local levels. In fact, what Navon and Norman proposed as a conclusion is an issue which needs further studies. This problem is investigated in the current chapter.

On the other hand, nonsignificant differences in RTs to the small letters in the single and the compound condition does not necessarily prove the determinant role of size in the global precedence hypothesis. It seems that the initial axiom of the global precedence effect was that global and local levels were equally complex, codable, recognisable, and

one is not predictable from the identity of the other (Kimchi, 1992). Therefore, any difference in the reaction times to the global and local levels has been interpreted as a result of a change in the speed of processing of any or both of the levels in comparison to their speed of processing when they were presented individually. That is, the temporal global dominance may be a result of a decrease in the speed of processing of the local level, or an increase in the speed of processing of the global configuration, or both in comparison to the speed of processing of their individual presentation. Navon and Norman (1983) considered this without testing it precisely. In fact, by proposing the idea that size is the determinant of the global precedence effect, they challenged the assumption which was initially proposed by Navon (1977). According to this hypothesis "perceptual processes are temporally organised so that they proceed from global structuring towards more and more fine-grained analysis. In other words, a scene is decomposed rather than built up" (Navon, 1977, p. 354).

The Rationale and Purpose of the Present Study

If only size is the major factor influencing the global precedence effect, it seems reasonable to study the validity of the initial axiom which has been accepted by the majority of studies conducted within this paradigm. Navon and Norman (1983) did not find a significant difference in the reaction times to the small figures when they were presented as single letters compared to the condition in which they were exposed as local properties of a compound shape. However, this finding does not rule out the possibility of faster reaction times to the global property in comparison to the reaction time to that property when it was presented individually. In fact, we do not know what will be the reaction times to a single pattern as large as a global configuration, when the structural relationship between the global and local levels is ruled out. Therefore, it may be argued that a compound global stimulus is more salient than a single figure of the same size. In fact, in the global-precedence hypothesis as "the modern version of the Gestaltist claim," (Kimchi, 1992, p. 24) the perceptual primacy of the global configuration has been attributed to some emerging properties of the whole, and not to the slower reaction time to

the local elements when they are embedded within a compound structure. Therefore, although Navon and Norman's findings provided some valuable data about this hypothesis, they did not provide a consistent argument about size as the sole determinant of the global advantage. The first thrust of this series of experiments is to test the initial logic behind the "global precedence hypothesis" about the equal recognisability of the two levels, the axiom which has been being accepted without being tested.

Meanwhile, there was a substantial difference between the studies of Kinchla and Wolfe (1979) and Navon and Norman (1983) which makes the generalisation of the findings from one to the other difficult. The former study was conducted under size/eccentricity uncertainty conditions.² In other words, in the study by Kinchla and Wolfe stimuli of different sizes and eccentricities were mixed within a block in a random order. Thus, the subjects had to expect stimuli of different size/eccentricity on each trial. In the latter study, however, there were only two size/eccentricity conditions which were blocked within separate blocks. Therefore, it may be argued that the difference in the results between two studies was the result of the variations in the experimental presentation conditions. In one study subjects were to expect compound patterns of five different sizes and eccentricities within a block but in the other study the stimuli of a certain size and eccentricity were displayed within a given block.

The visual system is reported to be selectively sensitive to the spatial frequency and location of the stimulus (e.g., Cohen & Lasley, 1974; Davis, 1981; Davis & Graham, 1981; Posner & Snyder, 1975; Posner, Snyder, & Davidson, 1980). Decreased performance was found in a detection task when subjects were uncertain about the spatial frequency or spatial position of sinusoidal grating (Davis, Kramer, & Graham, 1983; Shapley & Lennie, 1985). To study the possible confound of the global advantage effect with the size/eccentricity uncertainty I conducted experiments with stimuli similar to those used in Navon and Norman's (1983) first experiment in which local elements were

² Throughout this research the term size/eccentricity refers to a condition in which variations in size of the stimulus are accompanied by the variations in eccentricity.

located in the perimeter of the global configuration, but under size/eccentricity uncertainty conditions. To be able to trace the possible effect of eccentricity on RTs to the two levels, nine series of stimuli with different sizes were presented to nine different retinal eccentricities. Therefore, the second thrust of this series of experiments in this chapter is to test the possible effect of size/eccentricity uncertainty on the temporal order of processing of the global configuration and local components and to trace the effect of eccentricity.

Navon and Norman (1983) considered the role of eccentricity simply to read to a decrease in visual acuity as the image of an object moves from the fovea to the periphery. They found that eccentricity exerted an influence which appears to neutralise the size effect. Therefore even if their argument that size is the major determinant of global advantage is valid, the most rational conclusion from their study would be that, both eccentricity and size have strong effects on the temporal order of processing. Because, although the visual angle of the global configuration in their large visual angle condition was reduced 8.625 times, a reduction of 8.5 times in eccentricity was able to compensate for the possible size effect. However, this neutraliser or counter-balancer may not have a continuous effect. Therefore, the third objective of the present study is the investigation of the effect of eccentricity and size and their possible interaction on the temporal order of processing of the two structural levels.

An Outline of the Experiments of This Chapter

Navon and Norman (1983) proposed that Kinchla and Wolfe confounded global advantage and eccentricity. This conclusion may be true, but these two studies were conducted under different experimental designs. The latter study was performed in size/eccentricity uncertainty condition, but the former was conducted under size/eccentricity certainty condition. Experiments 2A, 3A, and 4A were designed to test the effect of size/eccentricity uncertainty and certainty in the order of processing of the global and local levels in an experimental condition in which the eccentricities of the two levels were equated.

In these three experiments, subjects were presented with either large Cs made up of small circles or large Os made up of small Cs (see Figure 12). There were nine sets of stimuli of different sizes and eccentricities. Experiment 2A was conducted under size/eccentricity uncertainty and randomised (divided attention) conditions. Randomised condition refers to an experimental condition in which the property of opening may be exposed randomly either at the global or local level. That is the four stimuli in Figure 12 were presented within the same block in a random order. Therefore, subjects were required to identify the direction of the C either at the global or local level. Experiment 3A was performed under blocked experimental presentation (selective attention) and size/eccentricity uncertainty conditions. The Block experimental presentation refers to a condition in which Cs made up of small Os were presented in one block (the global block), and Os made up of small Cs within another block (the local block). That means the global and local targets were displayed within separate block. Experiment 4A was conducted under blocked experimental presentation and size certainty condition. That is before each experimental block subjects were informed whether the target property will be at the global or local level, and within each block only stimuli of a certain visual angle size were displayed.³

Navon and Norman (1983) indicated that relative size is the major determinant of global advantage. As was mentioned above, in their control condition Navon and Norman measured the reaction time to single Cs facing the right or the left, exposed at the highest position of the compound pattern in a 'selective attention' presentation condition. The results indicated no significant difference between the RTs to the local elements of the test and control conditions. Based on this and their other finding they suggested that size is the determinant of globality. Navon and Norman chose only two series of stimulus

³ Since the instructions to attend selectively or to divide the attention do not guarantee the strategy employed by the subjects (See, Navon and Norman, 1983), in the present study the concepts of blocked and randomized presentation conditions are used, referring to experimental conditions than the possible strategy employed by subjects.

eccentricity (1° and 8.5°). Although in their control condition the local elements were displayed as a single stimulus, the speed of processing of the global level was not compared with the single control stimuli of the same size. Therefore, it may be argued that the difference in the reaction times to the global figures and the respective single locals was because of the facilitation which was carried out by the perceptual system in favour of the global configurations. In other words, it may be argued that the difference in the response times to the two levels was not as the result of an increase in RTs to local components but it was as a facilitation in favour of the processing of the global configuration. Meanwhile, Navon and Norman's study was conducted with two series of stimuli displayed at two eccentricities and only in the blocked presentation condition. Thus, its results are not generalisable to other experimental conditions.

Experiments 2B, 3B, and 4B were designed to clarify the possible role of size and eccentricity on the relative reaction times to the global and local levels. Therefore, series B experiments were exact replications of series A experiments, respectively, when the stimuli of any of the global and local figures were replaced by a single C of the same size and eccentricity. Therefore, similar to Experiments 2A, 3A, and 4A, the eccentricities of the stimuli of series B experiments varied in 9 conditions between 0.25 and 8.15 degrees. Meanwhile, Experiment 2B, 3B, and 4B were designed to examine the effect of the hierarchical structure of compound patterns on the response times to the global and local levels. It was assumed that nonsignificant difference between RTs to either the global or local level of a compound pattern and a single stimulus of the same size and eccentricity indicates that the difference in the response times to the global and local levels is not produced by the hierarchical structure of the compound pattern. Such a finding may suggest the active involvement of size and eccentricity in the global advantage effect.

In Experiment 5 the effect of eccentricity was studied independently of the effect of size, measuring the reaction times to a single C of a constant size directing to the right or to the left when it was displayed at locations of various eccentricities. Experiment 6 measured the effect of size, independently of eccentricity, by displaying Cs of various sizes at a location of constant eccentricity.

Incompatibility in Position: The selection of a correct response has been suggested to depend on the position of a stimulus (e.g., Nicoletti & Umiltà, 1985, Simon, Sly, & Vilapakkam, 1981). The right side stimulus is suggested to be compatible with the right side response, and incompatible with the left side response. The response time is faster to the compatible than to the incompatible pairings (Teichner & Krebs, 1988). It has been suggested that left-right compatibility has some attentional origin (Nicoletti & Umiltà, 1985). However whatever is the source of left-right compatibility, it produces serious problem when a property associated with directionality is responded to with an incompatible hand. In all the experiments of the present research the responses were related to the position of the stimuli, either to the right or to the left. In the preliminary pilot study I found it very disturbing when subjects were required to respond to a property that was associated with right left differentiation with the opposite hand. Therefore except for Experiment 1 in 11 out of 12 experiments of this thesis hand key appointment was not counter-balanced.

4.1 Experiment 2A

The difference between the results of Navon and Norman (1983) and Kinchla and Wolfe's (1979) study may be attributed to the difference in their experimental conditions. The first study was conducted under size/eccentricity certainty condition. The second experiment, however, was carried out in a size/eccentricity uncertainty condition. The effect of size/eccentricity uncertainty in a condition in which the eccentricities of the global and local levels are equated has not previously been reported. Experiment 2A was designed to study the effect of size/eccentricity on the global advantage in uncertainty conditions. Stimuli of nine series of visual angle sizes were employed in this experiment. They all were mixed within a randomised presentation condition. The task was the identification of the direction of the opening of a C either at the global or the local level. The main objective of this experiment was to study the effect of size/eccentricity uncertainty on the speed of processing of the two structural levels. This experiment also

investigated the effect of size/eccentricity over a greater range of the size of the compound pattern than used by Navon and Norman (1983).

Method

Subjects

Subjects were 17 undergraduate right-handed students of the University of Wollongong. All reported normal or corrected to normal vision. They received either some course credit or money in return for their participation. Each subject participated in one experimental session of approximately 50 to 60 minute duration.

Apparatus and Stimuli

Stimulus patterns were programmed and generated by an IBM AH compatible computer. Stimuli were displayed on a VGA monitor. The RT resolution of the software was 1 msec, and the refreshment rate was about 16 msec. The monitor had a matrix size of 640 x 480 pixels. Each pixel was associated with an image of 0.37 mm in length and 0.39 mm in width of the monitor. The stimuli were made of number of pixels per element. The stimuli were either large Cs made up of small Os or large Os made up of small Cs (Figure 12). There were 16 small Cs in the perimeter of large Os and 13 small Os in the perimeter of large Cs. There were nine series of stimuli. Within each series the eccentricities of the global and local levels were equal. The eccentricity of each stimulus was half of the visual angle of the size of the global configuration of that stimulus. The global figures of the stimuli had one of the nine following visual angles: 0.5°, 1.1°, 2.4°, 4.7°, 7.2°, 9.6°, 12.0°, 14.3°, and 16.3°. The visual angles of the local elements of the stimuli were about one eighth of the global configurations, respectively. The probabilities of occurrence of any of the four shapes illustrated in Figure 12 of any of the nine above mentioned visual angles were the same. In fact there were 4 by 9, That is 36 stimuli in this experiment. The sizes of the openings of both global and local Cs of all stimulus sizes were 72° of their perimeters.

The mask stimulus was exactly similar to the one used in Experiment 1. Since the viewing distance was 60 cm in this experiment, the visual angle of each mask element was 0.30 degree. The average distance of the centre of each mask element from the centres of adjacent elements was approximately 0.48 degree. Viewing was binocular. The subjects' heads were stabilised in a chin rest while the stimuli were displayed randomly, centred on the middle of stimulus field. The experiment was conducted in a darkened room. The luminance of the monitor was decreased not to hurt the subjects' eyes and to decrease after images. The target, mask, fixation stimuli were all white on a black background, giving a very high contrast. The luminance of all stimulus events measured by TEKTRONIX J6526 1° Narrow angle luminance probe, was approximately 2 cd/m².

Figure 12. The set of stimuli used in Experiments 2A, 3A, and 4A.

Design and Procedure

The subjects sat with their chin on a chin rest located 60 cm from the monitor screen. Subjects were tested individually in a single session. Each experimental session consisted of one tutoring tour, one practice and six experimental blocks. A session began with a programmed tour on the nature of the task and the requirements. Subjects were advised that they were required to respond to the direction of the opening of a C either at the global or local level. The first block was for practice and its results were not included in the analysis. Each block consisted of 72 trials, arranged randomly from among any of the nine visual angle series of the four patterns presented in Figure 12. Therefore, the target feature which was the direction of the opening of a C, either to the right or to the

left, was located randomly at either the global or local level. As was mentioned previously, this type of experimental presentation was called the 'divided attention' condition by Navon and Norman (1983). In the present study, this sort of presentation in which four stimuli of Figure 12 were presented within the same block in a random order will be called the randomised presentation condition.

The subjects were required to fixate at the centre of the monitor. To ensure central fixation, each trial was initiated by the onset of either a "+" or an "x" in the middle of the screen as the first fixation stimuli, measuring a visual angle of about 0.05 degree. Subjects were required to press a specially marked key with the index finger of their right hand if the fixation stimulus was a "+", and another specially marked key with the index finger of their left hand if the fixation stimulus was an "x." The fixation stimulus stayed on the screen until the subjects responded. Immediately after responding to it, the test stimuli appeared on the screen for 100 msec. Concurrent with the test stimulus, again, either a "+" or an "x" of the same size as the first fixation stimulus was displayed in the middle of the screen as the second fixation stimuli. The location of the second fixation stimulus was the same as the first one. The identity of the second fixation stimulus might or might not be the same as the first one. Subjects were required to notice the identity of the second fixation stimulus and were verbally questioned in about 15 percent of the randomly selected trials. This interrogation was performed to force the subjects to fixate at the fixation point all the time and to prevent possible eye movements (Navon & Norman, 1983).

The test task was to press a specially marked key with the right index finger if the opening of the C either at the global or the local level was directed to the right, or another specially marked key with the left index finger if the target C pointed to the left. The test stimulus was replaced by the mask stimulus. The mask disappeared after the correct response, or after a time-out of 2000 msec. Only wrong responses were followed by an auditory feedback. The next trial began 1000 msec after the off-set of the mask stimulus. Subjects were instructed to be both accurate and quick. Reaction times and accuracies to

the test stimuli and the accuracies to the verbal responses to the second fixation stimuli were recorded.

Results and Discussion

Two subjects were excluded from analysis due to their extremely high error rates. The means and standard deviations of the response times and response accuracies to the global and local figures in any of the nine eccentricities are shown in Table 5 (Appendix B) and Figure 13. The data entered the analysis and graphed were derived from means of the subject's means. The data were analysed by a five factor repeated measures analysis of variance (ANOVA). The factors were eccentricity (9 conditions), target level (global versus local), the direction of the opening of the target figure (left versus right), the identity of the first fixation stimulus (+ versus x), and the identity of the second fixation stimulus (+ versus x). Average correct reaction times were calculated for all of the cells of the design for each subject. The analysis indicated that the global figures were identified significantly faster than the local components (Figure 13), $F(1, 14) = 780.90, p < 0.0001$. The extent of global advantage varied across eccentricity. This was indicated by a significant target level X eccentricity interaction, $F(8, 112) = 75.95, p < 0.0001$, and by a significant main effect of eccentricity, $F(8, 112) = 147.16, p < 0.0001$. This means that eccentricity had a greater effect on either the global or local level than the other. Also it probably reflects the very long RTs with local components at the smallest size/eccentricity condition.

Although overall effect of direction was not significant, local elements with an opening to the right (left visual field) were detected faster than those with an opening to the left (right visual field). Further inspection of patterns of responses to the direction of the opening of the target figure indicated that except for the stimuli with an eccentricity of 3.6° , the opening projected to the left visual field (a C with an opening to the right) was detected significantly or considerably faster than the condition in which the opening was projected to the right visual field. This was reflected in the significant interactions

between target level and direction, $F(1, 14) = 7.99$, $p < 0.0071$, and between eccentricity and direction, $F(8, 112) = 7.91$, $p < 0.0001$.

All subjects achieved a high degree of accuracy in their responses, with an overall accuracy proportion of 1.00 (standard deviation = 0.02) for the global configuration and 0.99 (SD= 0.05) for the local elements (Table 5, Appendix B). Since the variation in accuracy rates across subjects and according to target level and eccentricity was considerably high (10%), a similar analysis was conducted on the accuracy proportions. Again, the data were analysed by a five-way repeated measure ANOVA. The factors were

Figure 13. Mean RTs as a function of target level and eccentricity in Experiment 2A.

the same as those for the RT analysis. Two of the five main factors were significant: target level and eccentricity. The global level was identified significantly more accurately than the local level, $F(1, 14) = 12.97$, $p < 0.0008$. The significant main effect of eccentricity, $F(8, 112) = 4.53$, $p < 0.0001$; and the significant interaction between target level and eccentricity, $F(8, 112) = 4.37$, $p < 0.0001$; reflected the variation of accuracy

level across eccentricity, especially the high error rate to the local level at the smallest size/eccentricity condition. Meanwhile, the interaction of target level and direction was significant, $F(8, 112) = 8.17$, $p < 0.0065$. The overall error proportion for the verbal identification of the second fixation stimulus was 0.02 (standard deviation = 0.01). This low error rate to the identification of the second fixation stimulus indicated that subjects centrally fixated, as they were required. Since this proportion was considerably low, further analysis was not conducted on it. There were no other significant interactions of interest in the RT and accuracy analyses (Tables 13 & 14, Appendix B). Accuracy analysis indicated that pattern of reaction times cannot be due to the speed-accuracy trade-off, because in all significant conditions faster RTs were associated with higher accuracy rates.

The results of this experiment showed that in a randomised condition when the eccentricities of global and local levels were equated, the global configuration was processed faster than the local elements under size uncertainty conditions. The temporal order of processing did not change in favour of the local elements as the visual angle of both global and local levels proportionally increased. Therefore, the results of this study did not confirm Kinchla and Wolfe's (1979) findings about the presence of a turning-point in the order of processing of the global and the local levels as a function of the visual angle of the stimulus. As a result, it does not seem that size/eccentricity uncertainty was the origin of the turning point in the direction of global advantage in Kinchla and Wolfe's (1979) experiment. Therefore, global advantage was not influenced by the uncertainty about the size/eccentricity of stimuli in the randomised condition. Meanwhile, the results of this study did not agree with the findings of Navon and Norman (1983) about the nonsignificant effect of eccentricity. These workers did not find any significant difference between the response times to the stimuli of the large and small visual angles. However, the present experiment indicated that RTs to the identification of both levels were significantly influenced by eccentricity. This was shown by quadratic patterns of responses to the global and local levels illustrated in Figure 13.

Using the method of least squares to fit a general linear model indicated that the pattern of reaction times were best fitted a quadratic function of $y = 395.59 - 17.593x + 2.1662 x^2$, $R^2 = 0.767$ [$F(8, 112) = 126.45$, $p < 0.0001$] for the global level; and with the equation of $y = 567.36 - 69.906x + 7.1714x^2$, $R^2 = 0.51$ [$F(8, 112) = 715.06$, $p < 0.0001$] for the local level. These patterns indicate that as eccentricity increased the speed of responses to both global and local levels increased up to a certain eccentricity, but with further increase in the eccentricity, speed of processing of the two levels decreased. However, this experiment did not clarify if the quadratic functions of the pattern of reaction times to the global and local levels were created by the hierarchical structure of the compound patterns (i.e., the compoundness of the stimulus pattern), experimental presentation conditions (i.e., randomised versus blocked conditions), size/eccentricity uncertainty, or any other effect. At this stage the results show that in a randomised presentation condition when the image of a compound shape proportionally increased, the speed of the identification of the global and local levels produced a U-shaped pattern as a function of eccentricity.

Faster reaction times to both global and local levels with an opening to the right in the present experiment were in contrast to studies reported hemispheric specialisation in the processing of the global and local levels (Lamb, Robertson, & Knight 1989; Robertson & Lamb, 1991; Treisman, 1986). Some other studies suggested variations in visual field advantage across eccentricity. For example, Sergent (1983a) found a right visual field advantage for pairs of letters when they were projected to eccentricity 2.5° . A left visual field advantage was reported by this worker when the same stimuli were projected to eccentricity 11° . The inconsistency of the results of the present experiment with Sergent's study and hemispheric specialisation literature may have resulted from the fact that in the present experiment subjects responded to the left and right openings by their left and right index fingers, respectively. Therefore, faster reaction times to the right-facing Cs may be related to the right hand dominance. In the preliminary pilot study I found it very inconvenient and interrupting when subjects were asked to respond to a target with an opening to the right with their left hand. There are similar reports by some

other workers (e.g., Boer & Keuss, 1982; Simon, Sly, & Vilapakkam, 1981) indicating that left-right position of the stimulus worked as an irrelevant directional cue for responding with left versus right response keys. Thus, response keys were not counter balanced between the subjects.

4.2 Experiment 2B

As mentioned previously, Navon and Norman suggested that size is the major determinant of the global advantage. This conclusion was based on the comparison of the response times to the local components when they were presented alone, with the reaction times to these figures when they were part of a compound shape. They did not find a significant difference between these two conditions. However, this comparison does not necessarily prove the superiority of the size effect because it may be argued that if the global configuration was displayed as a single figure, the reaction time to its identification may increase to the level of RTs to the local elements. On the other hand, Navon and Norman's data are not consistent with the literature on masking effects. For example, it is suggested that a feature embedded within a compound pattern is responded to faster than the condition in which that feature is responded to individually (e.g., Lasaga, 1989). Other studies (See, Johnson, 1986; Pomerantz, 1981; Wenderoth & Beh, 1977) have also suggested a decrease in RT when a target figure is flanked by the other target or nontarget figures. On the other hand, Murphy and Eriksen (1987) found that adjacent letters interfere with the response time to a target letter if flanking letters were within 1° visual angle of the target letter, when the subjects had previous knowledge about the location of the target letter. However, when the subjects were uncertain about the location of the target letter the interference was effective even up to 2-3 degrees from the location of the target.

Meanwhile, even if Navon and Norman's conclusions are valid, they do not necessarily prove that size was the determinant of globality. It may be argued that in a typical hierarchical figure the reaction times to the global configurations are facilitated in comparison to their individual presentation without a change in the speed of processing of

the local components presented singly. For example Pomerantz, Pristach, & Carson (1989) suggested that emergent features are more discriminable than component elements. This was called configural superiority effect (See section 1.2.7.1 of the present research). Therefore, it might be suggested that the origin of the global advantage is not in the slower processing of the local components in comparison to their speed of processing at a single presentation condition, but it is in the faster reaction times to robust global figures in comparison to a single stimulus as large as the global configuration. On the other hand, if Navon and Norman's argument is correct, the reaction time to any large stimulus must be less than any other stimulus of the same eccentricity but of a smaller size. In this case the global precedence effect may reduce to the difference between the sizes of two figures. Therefore, the attribution of size as the sole or major determinant of the global advantage is a matter which has to be established and it cannot be deduced only from the comparison of RTs to the small letters in the experimental and control conditions of the above mentioned study. In other words, any gain in favour of the global level has not to be necessarily assumed to be the result of an increase in RTs to the local components.

In Experiment 2A, it was shown that the global level was detected faster than the local elements of the same eccentricity regardless of the visual angle of the compound configuration. Meanwhile, it was found that the pattern of responses to the two levels varied according to the eccentricity. Experiment 2B was designed to test the pattern of responses when the local and global stimuli in Experiment 2A were replaced by single stimuli of the same size and eccentricity. Thus, the stimulus in Experiment 2B was either a large or a small single patterns of C facing the right or the left. There were two types of stimuli: 'similar to the global' and 'similar to local'. The 'Similar to global' stimulus was just a single C with an opening either to the right or to the left, with the same size as the comparative global figure of Experiment 1A, and was displayed at the same location as it was. The 'Similar to local' stimulus was also a single C facing either the right or the left and of the same size and eccentricity as the respective local stimulus used in Experiment 2A. Thus there were nine pairs of large single Cs occurring round the fixation point (central), and nine pairs of the small noncentral Cs displayed either at the highest or

lowest location of the comparative large Cs. The logic behind this study is that if a large single figure is detected faster than a small single figure with the same eccentricity, and if the difference between the reaction times is comparable to the difference between the reaction times to the global and local levels of the hierarchical patterns, it may be concluded that large central figures are detected faster than small noncentral figures of the same eccentricity regardless of the structure of the shapes (compound versus single stimuli). Therefore, Experiment 2B is a replication of Experiment 2A using single stimuli.

Method

Subjects

Fifteen right-handed subjects recruited from the same subject pool as previous experiments participated in this experiment. Each of the subjects served in a 50-minute session. All subjects reported normal or reported to normal vision.

Apparatus and Stimuli

The apparatus was the same as in previous experiments. The stimuli were divided into two groups: 'similar to global' and 'similar to local' Cs. The first group of stimuli was composed of nine pairs of single Cs facing either to the right or to the left with the same sizes and eccentricities as the global configurations of Experiments 1. The centres of the 'similar to large circles' were located in the middle of visual field at the same location as the fixation stimuli. That is both global and 'similar to global stimuli' were central. The 'similar to local' stimuli were nine pairs of eccentric Cs as large as any of the local elements of the nine series of stimuli in Experiment 2A. The "Similar to local" stimuli were displayed at the highest or the lowest locations of their respective local elements in Experiment 2A. On each trial either a 'similar to global' or a 'similar to local' stimuli was displayed. All other conditions of the apparatus and stimuli of this experiment were the same as Experiment 2A.

Design and Procedure

Subjects were advised that on each trial either a single C or a reverse C would be displayed on the screen of a computer just in front of them. The task was to press a specially marked key with the index finger of the right hand if the direction of the opening was to the right and another specially marked key with the index finger of the left hand if the direction of the C was to the left. The viewing distance from the screen and the visual angles of the stimuli were the same as the previous experiment. Any pair of "similar to global" stimuli had a respective pair of the same eccentricity from the "similar to local" stimuli. Both types of stimuli had equal probability of presentation. All nine series of the stimuli of the two types were mixed within a randomised presentation condition. There were 1 practice and 6 experimental blocks of 72 trials. To ensure central fixation, the other details of the method of this experiment were designed to be exactly the same as the corresponding ones in Experiment 2A.

Results and Discussion

Mean reaction times and accuracy proportions for each stimulus type in any of the nine eccentricities are displayed in Table 6 (Appendix B) and Figure 14. The reaction times were analysed by a five-way repeated measures ANOVA. The factors were target level ('similar to global' versus 'similar to local'), eccentricity (nine eccentricity levels from 0.25° to 8.15°), direction of the opening of the target figure (right versus left), identity of the first fixation stimulus (x versus +), and identity of the second fixation stimulus (x versus +). The 'similar to global' stimuli were responded to significantly faster than the 'similar to local' stimuli (Figure 14), $F(1, 14) = 861.98$, $p < 0.0001$. Since the eccentricities of the two levels were equated, the difference in their response times seems to be produced by the difference in their sizes, and/or the difference in eccentricity of the two stimulus levels. More importantly, the significant effect of eccentricity, $F(8, 112) = 57.13$, $p < 0.0001$; and the significant interaction of eccentricity and target level, $F(8, 112) = 11.57$, $p < 0.0001$; indicated that the factor of size/eccentricity yielded a significant effect. It means that the response times at each target level are probably

influenced by not only the relative sizes of the 'similar to global' and 'similar to local' stimuli, but also by the eccentricity of any of the two levels. Meanwhile, the significant interaction between target level and eccentricity seems to be produced by variations in reaction times across eccentricity and target level. Specially this interaction reflects the very long RTs with the 'similar to local' figure at the smallest size/eccentricity condition. Overall RT to the identification of the direction of the opening of Cs with an opening to the right was significantly faster than the reaction time to the Cs with an opening to the left, $F(1, 14) = 5.16$, $p < 0.0282$. However, further analysis based on the significance of the interactions between target level and direction, $F(1, 14) = 4.10$, $p < 0.0492$; and between eccentricity and direction, $F(8, 112) = 14.26$, $p < 0.0001$, indicated that pattern

Figure 14. Mean RTs as a function of target level and eccentricity in Experiment 2B.

of RTs according to the direction of the opening of the stimulus varied across target level and eccentricity. 'Similar to local stimulus' with an opening to the right was identified faster than the one with an opening to the left. At the 'similar to global' level speed of

processing of the C with an opening to the right was the same as the Cs with an opening to the left. The dominance of right/left opening changed across eccentricity.

Overall accuracy levels were 1.00 (SD= 0.02) for the 'similar to global' stimuli and 0.99 (SD= 0.06) for 'similar to local' stimuli (Table 6, Appendix B). Since the variation in the overall accuracy rate was considerably high across eccentricity, further analyses were conducted on the accuracy data. A five way repeated measure ANOVA was used similar to the RT analysis. The factors were the same as the factors in RT analysis. The proportion of accurate responses to the 'similar to global' stimuli which were identified faster, was significantly higher than the proportion of accurate responses to the 'similar to local' stimuli which were identified slower, $F(1, 14) = 34.57$, $p < 0.0001$. There was a significant main effect of eccentricity, $F(8, 112) = 2.82$, $p < 0.0048$. Also the interaction of target level and eccentricity was significant, $F(8, 112) = 2.29$, $p < 0.0214$. There were no other significant interaction of interest. The comparison of RT and accuracy analyses showed that the faster responses to the 'similar to global' stimuli and the variation of reaction time across eccentricity were not obtain as a speed-accuracy trade-off to the 'similar to local' stimuli. Mean accuracy level for the verbal identification of the second fixation stimuli was 0.99 (SD= 0.01). Since all subjects achieved a high degree of accuracy in their responses to the second fixation stimulus, no further analysis was carried out on this data. There were no other significant interaction of interest in RT and accuracy analyses (Table 15 & 16, Appendix B).

The patterns of response latencies to the two stimulus levels were further analysed to obtain a general linear model of the patterns of responses. The data indicated a strong suggestion of quadratic functions of $y = 399.32 - 14.338x + 1.8527x^2$, $R^2 = 0.726$ [$F(8, 112) = 193.01$, $p < 0.0001$] for the 'similar to global,' and the quadratic function of $y = 519.74 - 36.664x + 4.0701x^2$, $R^2 = 0.429$ [$F(8, 112) = 109.63$, $p < 0.0001$] to 'similar to local' figures.

Comparison of the Results of Experiments 2A and 2B

The strong similarity of patterns of results of Experiments 2A and 2B suggests that the differences in the speed of processing of the global configurations and their local components and the quadratic functions of RTs to the global and local levels across eccentricity are not determined by the hierarchical structure of the stimuli in Experiment 2A, but are probably formed by the difference in sizes, eccentricity, or experimental presentation condition (randomised presentation condition). To compare the patterns of responses in Experiment 2A and 2B, response times to the global and local levels of Experiment 2A, and 'similar to global' and 'similar to local' levels of Experiment 2B were compared. RTs were analysed using two different analyses of variance for mixed designs with stimulus structure (compound versus single figures) as the between subjects factor and eccentricity (9 levels) as the within subjects factor. The pattern of responses to the global level in Experiment 2A and 'similar to global' figures in Experiment 2B were compared by one ANOVA, and the pattern of responses to the local level in Experiment 2A and 'similar to local' level in experiment 1B were analysed by another ANOVA.

The overall ANOVA for the comparison of global and 'similar to global,' and the comparison of local and 'similar to local' figures revealed no between subjects effects. However, as expected within subject effects in the first comparison, $F(8, 112) = 63.89$, $p < 0.0001$; and the second comparison, $F(8, 112) = 296.05$, $p < 0.0001$; were significant. These within subject effects are, in fact, the main effects of eccentricities of the 'similar to global' and the 'similar to local' levels which were studied previously. The only significant interaction of the between and within subjects effects was in the study of the local and 'similar to local' stimuli in Experiments 2A and 2B, $F(8, 112) = 33.17$, $p < 0.0001$. This significant interaction was reflected in the pattern of responses illustrated in Figure 15. As can be seen in this figure, when the eccentricity of the figure is larger than 0.6° , non-single locals were identified faster than single locals. As the size and eccentricity of the stimuli get smaller, differences in RTs to the single and non-single stimuli decrease. Further decrease in the size and eccentricity of the stimuli changed RT dominance in favour of the single figures.

These analyses indicated that, in the randomised experimental presentation condition the reaction times to the global configurations were not significantly different from the reaction times to single figures of the same size. Nonsignificant difference between the RTs to the global and 'similar to global' stimuli, but a significant interaction between stimulus structure and eccentricity in comparison of the local and 'similar to local' stimuli suggests the possible involvement of a masking effect and the number of local elements in the identification of the local and 'similar to local' stimuli. As Figure 15 shows, as the compound shapes became smaller, local elements were responded to,

Figure 15. The comparison of patterns of responses in Experiment 2A and 2B.

slower in the context of a global shape than when they were presented individually. This pattern suggests the possible involvement of a masking effect produced by the other local elements at the adjacent locations when the compound shape is small. With further increases in the size of the global configuration, probably because of an increase in the distance between local elements, the masking effect disappeared. Meanwhile, the large

number of local elements in comparison to the individual presentations of Cs in an uncertain location, either at the highest or lowest location, played a positive role in increasing RTs to the identification of the local elements as a component of a compound shape than a single C. These data are consistent with the findings on the masking effect of adjacent figures on the processing of a target figure (e.g., Johnson, 1986; Murphy & Eriksen, 1987; Pomerantz, 1981; Wenderoth & Beh, 1977). Generally speaking, the similarity of the patterns of responses in Experiment 2A and 2B suggests the possibility of the involvement of both size and eccentricity as determinants of the global advantage. However, we do not know if the results of these two experiments are generalisable to the other experimental conditions. Experiments 3A, 3B, 4A, and 4B were designed to test the generalisability of the findings of Experiment 2A and 2B.

4.3 Experiment 3A

In Experiment 2A the effect of size uncertainty was studied when the four stimuli a, b, c, and d in Figure 12 were mixed within a block in a random order. Presumably, in such a randomised condition subjects have to divide their attention between the local and global levels. That means in each trial they must expect to perceive the target letter in either the global or local level. It may be argued that the dominance of the global level in that experiment was because of the division of attention between the global and the local levels and if subjects' attention was directed to only one level, the dominance of the global level may disappear. In Experiment 3A the effect of size/eccentricity uncertainty was studied in a condition in which attention was not divided between the two levels, a blocked presentation condition. Therefore, the stimuli of type a and b were blocked within one block and the stimuli of type c and d were blocked within another block. This type of experimental presentation will be called blocked presentation through out this study. Again, the logic behind the study was to test the effect of variation in the size of stimulus on the global advantage under size/eccentricity uncertainty conditions. In this experiment I also wanted to determine if the quadratic patterns of responses found in

Experiment 2A and 2B vary by the manipulation of the experimental presentation condition.

Method

Each of the 16 subjects served in a session of 50 to 60 minute duration. They were recruited from the same subject pool as Experiment 2A and 2B. All details of the method of this experiment were identical to the corresponding ones in Experiment 2A, except for the following. The global and local target figures were blocked in separate blocks. In fact, Experiment 3A was conducted under the size/eccentricity uncertainty plus blocked experimental presentation (selective attention) conditions. Each experimental session consisted of one tutoring tour, two practice, and 6 experimental blocks. The data of the practice blocks were not included in the analysis. One of the practice blocks was for the identification of the openings of the large Cs (shapes a and b) and the other for the identification of the openings of small Cs (shape c and d). Three of the experimental blocks were assigned for the identification of the opening of the C at the global level and the other three for the identification of the openings of the C at the local level. The order of the experimental blocks was counter balanced across subjects. Before each block, subjects were advised if they should attend to the global or local level. There were two practice blocks of 36 trials each, one for the global and the other for the local target figures. The number of trials per experimental block was 72. The order of the experimental blocks was counter balanced within the subjects. Within each block trials were presented in random order. The experiment was conducted in a single session.

Results and Discussion

One subject was excluded from analysis due to her extremely high error rates. The mean RTs and accuracy proportions of the global and local levels are tabulated in Table 7 (Appendix B) and Figure 16. Analyses were the same as in Experiment 2A. Three out of the five main effects were significant. Subjects responded to global targets overall faster than the local targets (Figure 16), $F(1, 14) = 2791.20$, $p < 0.0001$. Response latencies

varied across eccentricity. This was reflected in the significant main effect of eccentricity, $F(8, 112) = 465.34$, $p < 0.0001$. There was a significant interaction between target level and eccentricity, $F(8, 112) = 276.87$, $p < 0.0001$, indicating variations in the differences in RTs to the global and local levels across eccentricity. This probably largely reflects the very long RTs to local components at the smallest size/eccentricity condition. Although the overall main effect of direction was significant, $F(1, 14) = 39.26$, $p < 0.0001$, only

Figure 16. Mean RTs as a function of target level and eccentricity in Experiment 3A.

local elements with the opening to the right were identified considerably faster than those with an opening to the left. This was reflected in the significant interaction of target level and direction, $F(1, 14) = 15.11$, $p < 0.0001$. The right opening advantage varied across eccentricity. This was shown by the significant interaction between eccentricity and direction, $F(8, 112) = 2.31$, $p < 0.0001$. There were no other significant effect of interest in RT analysis (Table 17, Appendix B).

A similar analysis was conducted on accuracy proportions. The factors and conditions were the same as the those in the RT analysis. Three out of five main effects were significant: target level, $F(1, 14) = 55.93$, $p < 0.0001$; eccentricity, $F(8, 112) = 28.67$, $p < 0.0001$; and direction, $F(1, 14) = 11.00$, $p < 0.0018$. In addition, the interactions between target level and eccentricity, $F(8, 112) = 33.68$, $p < 0.0001$; between target level and direction, $F(1, 14) = 5.18$, $p < 0.0278$; and between eccentricity and direction, $F(8, 112) = 6.27$, $p < 0.0001$, were significant. There were no other significant interactions of interest (Table 18, Appendix B). The comparison of the results of the RT and accuracy analyses demonstrated that RT findings cannot be attributed to a speed-accuracy trade-off. The overall error proportion to the second fixation stimulus was 0.01 (SD = 0.01). Since this error rate was low no further analyses were conducted on it.

Mean response times to the global and local levels as a function of eccentricity location are illustrated in Figure 16. The results indicated that the global configurations were responded to faster than their local elements with all eccentricities and visual angle sizes. The patterns of reaction times to the global and local levels according to eccentricity were identified. The results of an analysis of least squares to fit a general linear model, provided a strong suggestion of a quadratic function of $y = 375.48 - 15.506x + 1.920x^2$, $R^2 = 0.796$ [$F(8, 112) = 32.24$, $p < 0.0001$] for the pattern of RTs of the global level; and the quadratic function of $y = 602.22 - 83.615x + 8.5258x^2$, $R^2 = 0.504$ [$F(8, 112) = 531.55$, $p < 0.0001$] for the local level.

From the above results, it may be concluded that in the blocked experimental condition where subjects were uncertain about the size/eccentricity of the stimulus no point was identified beyond which local stimuli were processed faster than global stimuli. This is in contrast to the findings of Kinchla and Wolfe (1979) about the presence of such a turning point as the function of visual angle of the stimulus. However, the data provides some evidence in favour of "middle-out" processing which was proposed by these workers. The present data show that as the image of a figure (either at global or local level) moved from a foveal location towards the periphery the response time decreased

gradually about the eccentricity of 2.36° (visual angle size of 4.7°). However, with a further increase in eccentricity, reaction times increased again.

The significant effects of eccentricity and the interaction between eccentricity and globality, are in contrast with the findings of Navon and Norman (1983) in their Experiment 1, on the nonsignificant effect of visual angle size. They interpreted their findings as evidence suggesting that the global advantage does not change as a function of the size of the global figure. They did not obtain any significant effect according to the visual angle of size/eccentricity, probably, because they had only two stimulus sets of eccentricities, 1° and 8.5° . In the present experiment, where stimuli of different eccentricities were used, significant effects of eccentricity and the interaction of globality and eccentricity were obtained. These two significant effects indicate that although the direction of globality did not change, there were significant variations in the response times according to the eccentricity.

4.4 Experiment 3B

This experiment was designed to test if the faster response time to the global level and the pattern of responses to the global and local levels in the previous experiment originated from the nature of the hierarchical structure of the stimulus configuration or whether some other factor was involved. To control the effects of all other factors except for the hierarchical structure all experimental conditions were kept the same as the experiment 2A. The main objective of this experiment was to discover the source and the locus of the global advantage.

Method

The sixteen subjects in this experiment were selected according to the same criteria as the previous experiments. All of the details of the method of this experiment were the same as Experiment 3A except for the stimulus type. In the present experiment, the global and local stimuli of Experiment 3A were replaced by single Cs of the same size. That means instead of a global C made up of small Os, there was only a single large C as large

as the global configuration; and instead of the local components only a single C as large as any of them was displayed either in the highest or lowest locations of their respective global configurations. Similar to Experiment 2B, the first type of stimulus was called 'similar to global' and the second type was named 'similar to local' stimuli. In fact, the present experiment was different from Experiment 3A only in the stimulus type, and varied from experiment 1B, only in the experimental presentation condition. Using the terminology used in the previous experiments, this experiment was conducted under size/eccentricity and blocked ('selective attention') presentation condition.

Results and Discussion

One subject was excluded from analysis due to his extremely high error rate. The average response times to the correct responses for each of the stimulus types were calculated and differentiated according to nine eccentricity conditions and the global versus local levels (Table 8, Appendix B). These are shown in Figure 17. Analyses were the same as Experiment 2B. Two out of five main effects were significant. The 'similar to global' level was identified faster than the 'similar to local' level (Figure 17), $F(1, 14) = 1577.46$, $p < 0.0001$. The response latencies varied across eccentricity. This was reflected in the significant main effect of eccentricity, $F(8, 112) = 95.72$, $p < 0.0001$. There was also a significant interaction between target level and eccentricity, $F(8, 112) = 31.79$, $p < 0.0001$. This shows that the difference between reaction times to the global and local levels varied across eccentricity. Also it probably largely reflects the very slow reaction times to local figures at the smallest size/eccentricity condition as can be seen in Figure 17. Although there was not any significant main effect of direction of opening or an interaction between direction and any other factor, 'similar to local' stimuli with the opening to the right were identified considerably faster than those with the opening to the left.

The overall accuracy proportion was 1.00 (SD= 0.01) for the 'similar to global' stimuli and 0.99 (SD= 0.04) for the 'similar to local' stimuli. Since the variation in the overall accuracy level of the local level was considerable, a repeated measures analysis of

variance was conducted on the accuracy proportions. Factors and conditions were the same as the factors and levels in RT analysis. 'Similar to global' stimulus was detected significantly more accurately than the 'similar to local' stimulus, $F(1, 14) = 28.41$, $p < 0.0001$. Also eccentricity as the main factor, $F(8, 112) = 3.90$, $p < 0.0002$; and the

Figure 17. Mean RTs as a function of target level and eccentricity in Experiment 3B.

interaction between stimulus level and eccentricity were significant, $F(8, 112) = 4.29$, $p < 0.0001$. This analysis ruled out the possibility that faster RTs to the 'similar to global' level and the pattern of responses across eccentricity may be attributed to a speed-accuracy trade-off.

The error proportion was 0.01 (SD= 0.01) for the verbal responses to the identification of the second fixation stimulus. Since this error proportion was considerably below the ceiling level for all subjects, further analyses were not conducted on it. There were no other significant interactions of interest in both RT and accuracy analysis (Tables 19 & 20, Appendix B). The best fitting functions for the patterns of

reaction times were $y = 370.25 - 13.684x + 1.7505x^2$, $R^2 = 0.703$ [$F(8, 112) = 200.45$, $p < 0.0001$] for the 'similar to global' stimulus; and $y = 522.98 - 31.576x + 3.5786x^2$, $R^2 = 0.386$ [$F(8, 112) = 403.89$, $p < 0.0001$] for the 'similar to local' stimulus. Patterns of responses to this experiment indicated that in the blocked presentation condition, proportional enlargement of the eccentricities and sizes of the 'similar to global' and 'similar to local' stimuli formed quadratic functions. The quadratic functions of the patterns of responses in this experiment indicate that in the blocked presentation condition by proportional enlargement of the eccentricities and sizes of the 'similar to global' and 'similar to local' stimuli, there is a minimum point in the pattern of RTs somewhere in the middle of the visual field. Generally the results of the present experiment indicated that the 'similar to global' stimuli were responded to faster than their respective 'similar to local' figures. This was irrespective of the visual angle size of any pairs of 'similar to global' and 'similar to local' shapes.

Comparison of the Results of Experiments 3A and 3B

A closer inspection of the data of Experiments 3A and 3B was performed using an analysis of variance for mixed designs with stimulus structure (compound versus single figures) as the between subjects factor and eccentricity (nine eccentricity levels) as within subjects factor. The patterns of responses to the global and local levels of Experiment 3A were compared with the 'similar to global' and 'similar to local' levels of Experiment 3B, respectively. The results of the comparison of RTs to the global and 'similar to global' levels of the two experiments revealed only a significant effect of eccentricity, $F(8, 112) = 53.29$, $p < 0.0001$, which was expected. There was no other significant main effect or interactions of the main effects. The comparison of the pattern of responses to the local and 'similar to local' levels of the two experiments across eccentricity indicated only a significant main effect of eccentricity, $F(8, 112) = 394.75$, $p < 0.0001$. However, the interaction between stimulus structure and within subject factor was significant, $F(8, 112) = 88.09$, $p < 0.0001$.

Nonsignificant differences in the pattern of responses to the global and 'similar to global' stimuli, and significant interaction of stimulus structure and eccentricity in comparison of the local and 'similar to local' stimuli suggests the possible involvement of masking effects and the effect of number of local elements in the identification of the local and 'similar to local' stimulus. Figure 18 demonstrates an intersection in RT functions according to eccentricity/size of the stimuli. The local elements of a compound stimulus

Figure 18. The comparison of patterns of responses in Experiments 3A and 3B.

with a visual angle less than 1.2° were detected slower than the condition in which they were presented alone. The response times to the local elements of a compound shape with a visual angle larger than 1.2° were faster than the condition in which only a single figure as large as the local element was displayed either at the highest or lowest location of the compound configuration. At the visual angle of 1.2° the RTs to the single and compound patterns were almost the same. These data suggest that local elements are responded to slower within the context of a small global configuration than a large one. The foregoing

suggests the possibility of involvement of masking effects of the adjacent local elements on the perception of any of them when the visual angle of the stimulus is small. However, as the global configuration was increased in size, the masking effects may decrease or even vanish, and the large number of the compound stimuli in comparison to a single display may be a positive factor in decreasing the response time to the local elements of the compound shape in comparison to their single presentation.

4.5 Experiment 4A

The comparison of Experiments 2A and 3A rules out the possibility that the U-shaped RT functions were created with the variation in the randomised versus blocked experimental presentation conditions. However, it may be argued that the global advantage and the quadratic functions of RTs of global and local levels as a function of eccentricity were the result of size/eccentricity uncertainty conditions. For example, it may be suggested that because of the uncertainty about the size and eccentricity of the forthcoming stimulus, subjects directed their attentional band (LaBerge & Brown, 1986) to somewhere in the middle of the visual field. In other words, when subjects were uncertain about the size of the incoming stimulus, they might employ a strategy to attend to somewhere in the middle of the visual field, where they are able to attend to the other locations with the minimal effort (the sum of the distances of the centre of a line from a set of locations on that line is less than the sum of the distances of any other point of that line from the same locations).

There may be another interpretation of this response pattern based on the literature on the so called range effect hypothesis. This concept has been the topic of a number of studies in reading (see, e.g., Gordon, 1985; McConkie, Kerr, Reddix, & Zola, 1988; Vitu, 1991), attention (see, e.g., LaBerge & Brown, 1986; Olson, & Zeltner, 1989), and time estimation (see, e.g., Guay & Salmoni, 1988). Generally speaking, range effect refers to the hypothesis that subjects' subjective judgments are affected by the range of available stimuli. An example of range effect in visual perception refers to overshooting of saccades to near targets and undershooting to targets presented in further eccentricities.

In fact, the "range effect" hypothesis suggests that saccades toward isolated targets presented at variable eccentricities in one block of trials, tend first to land near the mean range of possible eccentricities (Kapoula, 1985). Coren and Hoenig (1972) talked about an effect that they called "global effect." According to these workers simultaneous presentation of two targets in peripheral vision forces saccade to land to the centre of gravity of the global configuration formed by the two targets.

In the present study although the subjects were required to fixate at the middle of the visual field using the first and the second fixation stimulus, there was still the possibility of the intervention of the confound of range effects in Experiments 2A, 2B, 3A, and 3B. For example, it may be argued that because of uncertainty about the size of the target stimulus, subjects over-attended to stimuli near fixation and under-attended to the more eccentric stimuli. Therefore, this tendency may have resulted in a preference to attend to a location at an average eccentricity.

In the experiments so far, stimuli of different sizes and eccentricities were presented within a block, while the subjects were required to fixate on the fixation stimuli at the centre. Thus, there may be a tendency to attend to the locations near the mean range of the possible eccentricities. As a result, the quadratic functions of reaction times to the global and local levels may be the result of an uncertainty about the size/eccentricity of the incoming stimulus. If this interpretation was correct, it seems reasonable to predict that replacement of the size/eccentricity uncertainty condition by a size/eccentricity certainty condition may change the pattern of responses to the global and local levels. The effect of size/eccentricity certainty-uncertainty as the possible source of the quadratic function of the pattern of responses was tested in Experiments 4A and 4B. In these experiments global advantage effect was investigated under size/eccentricity certainty conditions.

Method

Fifteen subjects recruited from the same subject pool as previous experiments were used. Each subject served in an experimental session of approximately one hour duration. All other aspects of the method of this experiment were the same as for Experiment 2 A

and 3A, except for the size uncertainty condition. In this experiment there were nine blocks of large Cs made up of small Os and nine blocks of large Os made up of small Cs, making 9 pairs of blocks of nine eccentricities. The eccentricities of the stimuli were the same as in Experiments 2A and 3A. Therefore, in this experiment each block contained either large Cs made up of small Os or large Os made up of small Cs of a certain size. Each experimental session began with a tutoring tour followed by two practice blocks composed of 18 trials each, one for global and the other for local stimuli. The practice stimuli were selected randomly from among one of the nine pairs of stimuli, and they were counter balanced across subjects. The data of the practice blocks were not included in the analysis. Practice trials were followed by 18 experimental blocks. The order of the experimental blocks was counter balanced across subjects. Before each block, subjects were advised if they should attend to the global or the local levels. The number of trials per experimental block was thirty-three. The results of the first nine trials of each block were not considered in data analysis. Other aspects of the design and the procedure of the experiment were exactly the same as Experiment 2A and 3A.

Results and Discussion

Mean correct reaction times and accuracy levels, and standard deviations of reaction times and accuracy proportions to the global and local levels of each eccentricity are illustrated in Table 9 (Appendix B) and Figure 19. Analyses were the same as in Experiment 2A and 3A. The results showed that response times to global configurations were faster than RTs to the corresponding local components (Figure 19), $F(1, 14) = 2393.64$, $p < 0.0001$. The response latencies to the global and local levels varied across eccentricity. This was reflected in the significant main effect of eccentricity, $F(8, 112) = 193.07$, $p < 0.0001$. The only significant first order interaction was that between target level and eccentricity, $F(8, 112) = 167.35$, $p < 0.0001$. This means that the difference between reaction times to the global and local levels varied across eccentricity. It probably largely reflects the very long RTs to the local level at the smallest size/eccentricity condition. Meanwhile, Cs with an opening to the right were identified faster than Cs with

an opening to the left, $F(1, 14) = 27.74$, $p < 0.0001$. No other main effect or interaction was significant (Table 21, Appendix B).

The overall accuracy proportions were 0.99 (SD= 0.01) for the global configurations, and 0.99 (SD= 0.03) for the local elements. A similar analysis was conducted on the accuracy proportions. The factors and their levels were the same as in

Figure 19. Mean RTs as a function of target level and eccentricity in Experiment 4A.

the RT analysis. The results indicated only a significant effect of target level, $F(1, 14) = 12.76$, $p < 0.0001$; a significant effect of eccentricity, $F(8, 112) = 4.68$, $p < 0.0001$; a significant effect of direction, $F(1, 14) = 7.26$, $p < 0.0001$; and a significant interaction of target level and eccentricity, $F(8, 112) = 3.59$, $p < 0.0001$. There were no other significant interactions of interest (Table 22, Appendix B). The accuracy analysis was compatible with RT analysis and none of the latency results could be attributed to a speed-accuracy trade-off. The overall error rate was very low to the verbal response with regard to the identity of the second fixation stimulus, 0.01 (SD= 0.01). Since this error rate was

considerable low, and had little variation across subjects, no further analysis was conducted on these data.

As illustrated in Figure 19, RTs to the global configurations were significantly faster than the RTs to the local elements across different eccentricities. The obtained results confirmed Navon and Norman's findings on the temporal precedence of the global level over the local level and extended the validity of their findings to a wide range of eccentricities from 0.25° to 8.15°. Meanwhile, similar to Experiment 2A and 3A, the pattern of results of the present study suggested a quadratic function of $y = 348.99 - 6.9182x + 1.1668x^2$, $R^2 = 0.819$ [$F(8, 112) = 41.63$ $p < 0.0001$] for the global level; and a quadratic function of $y = 529.44 - 61.551x + 6.3497x^2$, $R^2 = 0.484$ [$F(8, 112) = 434.06$, $p < 0.0001$] for the local level.

Comparison of the results of Experiments 2A, 3A, and 4A indicates that the global level is responded to faster than the local components, in both the size/eccentricity uncertainty versus certainty, and blocked versus randomised presentation conditions. Meanwhile, Experiment 4A ruled out the possibility that the U-shaped patterns of responses to the global and the local levels were created by size/eccentricity uncertainty condition. Together, the results of these experiments suggest two general conclusions. First, global configurations of compound patterns with a placeholder relationship are detected faster than their local components regardless of the presentation conditions (blocked versus randomised) and size/eccentricity conditions (uncertainty versus certainty). Second, the reaction times to the global and the local levels as a function of eccentricity/size produce quadratic functions. This pattern was not changed according to the randomised or blocked presentation condition, and size/eccentricity uncertainty or certainty condition. The results so far, provide evidence for the existence of an optimum stimulus eccentricity/size at which stimuli are responded to faster than at other locations. The location of this minimum eccentricity or turning point seems to be independent of the stimulus level (global versus local), experimental presentation condition (blocked versus randomised), and size/eccentricity certainty versus uncertainty condition.

4.6 Experiment 4B

Experiment 4B was exactly the same as Experiment 4A, except for the type of stimulus. The objective of this experiment was to examine if the obtained global advantage and the quadratic functions of the RT patterns of the global and local levels vary by the replacement of the hierarchical patterns with single stimuli.

Method

Fifteen subjects were selected from the same subject pool as the previous experiments. Most of the details of the method of this experiment were exactly the same as Experiment 4A with one exception. In the present experiment global and local stimuli were replaced with single stimuli of the same sizes as either the global or local levels. Similar to Experiments 2B and 3B, 'similar to local' stimuli were exposed either at the highest or lowest position of the respective eccentricity.

Results and Discussion

Mean reaction times, accuracy proportions, and their respective standard deviations for the two stimulus levels in any of the nine eccentricities are tabulated in Table 10 (Appendix B) and Figure 20. Analysis was the same as Experiments 2B and 3B. Significant main effects on RTs were found only for target level, eccentricity, and direction. As plotted in Figure 20, 'similar to global' figures were identified overall faster than their respective 'similar to local' stimuli in all of the nine eccentricities, $F(1, 14) = 3433.57$, $p < 0.0001$. The significant main effect of eccentricity, $F(8, 112) = 51.95$, $p < 0.0001$, reflects the variation of response latency across eccentricity. Again the significant interaction of target level and eccentricity, $F(8, 112) = 22.63$, $p < 0.0001$, indicates that the difference in reaction times to the global and local levels varied across eccentricity. Also it probably largely reflects the very long RTs with the local stimuli at the smallest size/eccentricity condition. Both global and local stimuli with an opening to the right were detected faster than those with an opening to the left, $F(1, 14) = 32.89$, $p < 0.0001$. This may be because of right hand dominance of the subjects.

The overall accuracy proportions of the 'similar to global' and 'similar to local' stimuli were 1.00 (SD= 0.01) and 0.99 (SD= 0.03), respectively. Because of the variation in the accuracy level across eccentricity, a similar analysis was conducted on the accuracy proportions. Two out of the five main effects were significant: target level, $F(1, 14) = 28.41$, $p < 0.0001$; and eccentricity, $F(8, 112) = 3.90$, $p < 0.0001$. Also the

Figure 20. Mean RTs as a function of target level and eccentricity in Experiment 4B.

interaction of stimulus level and eccentricity was significant, $F(8, 112) = 4.29$, $p < 0.0001$. There were no other significant effect of interest in both RT and accuracy analysis (Tables 23 & 24, Appendix B). The accuracy proportion of the 'similar to global' stimuli was significantly higher than the 'similar to local' stimuli. The pattern of accuracy proportion of the 'similar to global' and 'similar to local' stimuli, and accuracy proportions across eccentricity indicated that RT results cannot be due to a speed-accuracy trade-off. Using the method of least square to fit a general linear model indicated that the pattern of RTs to the global and local levels best fitted with a quadratic function. The best

fitting equation was $y = 346.34 - 4.6827x + 0.84149x^2$, $R^2 = 0.667$ [$F(8, 112) = 30.11$, $p < 0.0001$] for 'similar to global' stimuli and $y = 474.80 - 22.713x + 2.6661x^2$, $R^2 = 0.348$ [$F(8, 112) = 95.98$, $p < 0.0001$] for the 'similar to local stimuli'. The minimum points of the functions of large and small figure types were both located at the eccentricity 4.8° .

Comparison of the Results of Experiments 4A and 4B

The response times, across eccentricity, to the global and local stimuli of Experiment 3A and 'similar to global' and 'similar to local' stimuli of Experiment 3B were compared respectively. RTs were compared using the same analysis applied for the comparison of the results of Experiment 3A and 3B. The results indicated no significant main effect or interaction except for the main effect of eccentricity, $F(1, 14) = 20.84$, $p < 0.0001$, in comparison of the global and 'similar to global' patterns. However, the comparison of the local and 'similar to local' levels indicated that the two main effects and their interaction were significant: stimulus structure as the between group factor, $F(1, 14) = 12.37$, $p < 0.0015$; eccentricity as the within group factor, $F(1, 14) = 188.55$, $p < 0.0001$; and the interaction of the between group and within group factors, $F(1, 14) = 39.82$, $p < 0.0001$.

Nonsignificant differences between the response times to the global and 'similar to global levels,' and significant difference between the response times to the local and 'similar to local' stimuli, suggest the possible involvement of the effects of masking and number of elements of the compound shape. As Figure 21 indicates, there is an intersection in the patterns of response to the local and 'similar to local' stimuli. When the visual angle of the global configuration was more than 1.2° , its local elements were identified faster than the single presentation of those locals. In visual angle 1.2° , these two reaction times were close to each other. However, as the visual angle of the stimulus became smaller, single locals were identified faster than the locals as the structural components of a compound shape. The pattern of responses suggests the possible involvement of the masking effect on the local elements by the adjacent elements of the

compound shape, when the global configuration was fairly small. However, when the compound figure was large, this effect vanishes, and the number of local elements probably played a positive role in facilitating the reaction time to the local elements as the

Figure 21. The comparison of patterns of responses in Experiments 4A and 4B.

components of the compound shape in comparison to a single presentation of that figure. The similarity of the results of the Experiments 4A and 4B suggests that the difference in the reaction times to the global configurations and local elements was the result of the difference of size and/or the eccentricity of global configuration and local elements rather than hierarchical structure of the compound pattern.

Comparison of the Results of Experiments so Far

Experiments 2A, 2B, 3A, 3B, 4A, and 4B were designed to test the effects of experimental presentation, size, eccentricity, and hierarchical structure of the stimulus on the global advantage. These experiments demonstrated that the global and 'similar to

global' figures were identified faster than the local and 'similar to local' ones, respectively, regardless of the experimental presentation, and size/eccentricity certainty versus uncertainty conditions. Overall similarity of the results of series A and series B experiments rules out the possibility that the difference in response times to the global and local levels originated from the hierarchical structure of the compound pattern. Meanwhile, in all these six experiments proportional enlargement of the size and eccentricity of the stimulus produced a quadratic function across eccentricity. Similarities of patterns of RTs to the global and local, and 'similar to global' and 'similar to local' levels suggest that the quadratic pattern of response does not depend on the structural level (global versus local, or 'similar to global' versus 'similar to local'), presentation conditions (blocked versus randomised), or size/eccentricity certainty versus uncertainty condition.

There is a suggestion that visual performance improves when the attending area is compact in contrast to discontinuous (Podgorny & Shepard, 1983). If this argument is correct the response times should be better when the target is presented to one or two certain locations than the condition in which attention is spread over a large area. However, the comparison of the results of series A and B experiments indicated that the performance was generally better when local figures had to be identified as the components of a compound shape than in the condition in which they must be identified either at the highest or lowest location of a compound pattern. To prevent the possible shift in the allocation of attention to a certain location or possible eye movements of subjects, in series B experiments the 'similar to local' stimulus was projected either to the highest or lowest location of its respective compound pattern. The uncertainty in the location of the 'similar to local' stimulus might be another reason for the slower reaction time to the 'similar to local' stimulus in comparison to the local stimulus. Therefore the difference in reaction times to the local and 'similar to local' stimuli may be generated by the uncertainty in the location of 'similar to local' stimulus. This possible confound was of much less importance to me than the control of subjects' possible attentional shift and eye movement towards the 'similar to local' stimuli. Therefore in series B experiments I

preferred to accept the risk of the former possible confound, which was not the major matter of concern in these experiments, than the latter.

Meanwhile, the comparison of series A with the respective series B experiments suggests that the global advantage does not originate from the hierarchical structure of the compound patterns, the experimental presentation conditions, or size/eccentricity certainty and uncertainty. The similar patterns of responses in these experiments and significant faster speed of processing of the global and 'similar to global' in comparison to the respective local and 'similar to local' figures provide a strong suggestion of the involvement of common factors in determining the speeds of processing of series A and series B stimuli. These experiments were conducted in such a controlled condition that the two stimulus levels in any of these experiments have nothing in different except for their size and eccentricity. Therefore, it seems more than likely that those common factors may be size and eccentricity, and their possible interactions. As was mentioned, size and eccentricity have been confounded in the literature and in the first experiment reported here. The next two experiments were designed to unravel the effects of size and eccentricity.

4.7 Experiment 5

The results so far indicate that a global or 'similar to global' stimulus was identified, respectively, faster than a local or 'similar to local' figure of the same eccentricity. Meanwhile, these experiments suggest that a proportional enlargement of both single and compound stimuli results in a quadratic functioning of the response times across eccentricity, regardless of the target level (global versus local) and stimulus structure (compound versus single stimulus). These pattern of response suggests that size and eccentricity may act in opposite directions. The effects of size and eccentricity were not studied separately in previous experiments. Experiment 5 was designed to study the role of eccentricity independent of the effect of size. To do this, the pattern of reaction time was investigated in an identification task, where a stimulus of a fixed size was projected onto different eccentricities. The results of the previous studies demonstrate that

the joint effect of size and eccentricity was the same for the compound and single stimuli. Based on these results it seems reasonable to expect that size and eccentricity have the same effect on both single and compound stimuli. Consequently in Experiment 6 a single stimulus was used to study the effect of eccentricity.

Method

Fifteen subjects participated in this experiment. Each subject served in a session of approximately 50 to 60 minute duration. The details of the method of this experiment were the same as previous studies except as follows: a C of a constant size was projected to a range of different eccentricities. There were nine eccentricities, 0°, 1°, 2°, 3°, 4°, 5°, 6°, 7°, 8°. To determine any possible interaction between stimulus size and eccentricity, stimuli of four different sizes (1.20, 0.60, 0.30, and 0.15 degrees) were presented in separate blocks, conditions 1 to 4 respectively. In each series there were only two single Cs of the same size facing either the right or the left. The stimuli were displayed either at the highest or lowest location of any of the above eccentricities. Similar to the previous experiments the task was to press one of the two specially marked keys according to the direction of the opening of the Cs. There was one practice and eight experimental blocks. The practice stimuli were selected randomly from among one of the four stimulus series. The size of the stimuli used in the practice block was counter balanced across subjects. There were two experimental blocks for each stimulus series. The order of experimental blocks was random. The practice block contained 27 trials. There were 98 trials in each experimental block, the first 8 of which were practice trials. All other details of the method of this experiment, such as central fixation, the first and the second fixation stimuli, were the same as the corresponding ones in the previous experiments of this chapter.

Results and Discussion

Mean RTs and accuracy proportions to all of the four visual angle sizes in any of the nine eccentricities are tabulated in Table 11 (Appendix B), and Figures 22 and 23.

Number of cells (288) exceeded the capacity of the statistical package for data analysis. Thus, two separate repeated measures ANOVA were applied. A three way repeated measures analysis of variance was performed on RTs. The factors were stimulus size (four conditions), eccentricity (nine levels), and direction (right or left).

The main effect of stimulus size was significant, $F(3, 42) = 1541.88, p < 0.0001$,

Figure 22. Mean RTs as a function of eccentricity in Experiment 5 (four constant sizes).

with RT being shorter when the stimulus size was larger than when it was smaller (Figure 22). The response latency generally increased with an increase in eccentricity, $F(8, 112) = 446.87, p < 0.0001$. However, the rate of increase in RTs with increase in eccentricity was larger with smaller stimuli than the larger stimuli (Figure 22). This was reflected in the significant interaction between stimulus size and eccentricity, $F(24, 336) = 29.79, p < 0.0001$. Another two-way repeated measure ANOVA was conducted on the fixation points. The factors were identity of the first fixation stimulus (x or +), and identity of the

second fixation stimulus (x or +). No significant main effect or interaction was obtained from this analysis.

A similar analysis was conducted on accuracy proportions. Again there was a main effect of stimulus size, $F(3, 42) = 719.37, p < 0.0001$; and a main effect of eccentricity, $F(8, 112) = 144.85, p < 0.0001$. Also the interaction of size and eccentricity was significant, $F(24, 336) = 47.18, p < 0.0001$. The main effect of size arose from the fact

Figure 23. Mean accuracy as a function of eccentricity in Experiment 5 (four constant sizes).

that accuracy rate was higher with the large than with the small stimuli. The main effect of eccentricity and the interaction of size and eccentricity reflect the decrease in the accuracy rate across eccentricity, and also the variation of the accuracy rate across eccentricity according to the size (Figure 23). The results of the analysis on the accuracy rates to the first and second fixation stimuli did not indicate any significant main effect or interaction. There were no other significant main effects or interactions in both RT and accuracy analysis (Table 25 & 26, Appendix B). The error rate to the verbal response to the second

fixation stimulus was 0.01 (SD= 0.01). Since this error rate did not indicate much variation between subjects no further analysis was applied on it. The comparison of RT and accuracy analysis suggests that none of the results of the latency analysis could be attributed to a speed-accuracy trade-off (Figures 22 & 23).

Considerably high variations of the accuracy proportions across subjects according to the size and eccentricity necessitates more detailed inspection of the data. Generally the accuracy rate decreased (i.e., error rates increased) with a decrease in the stimulus size, and with an increase in the eccentricity. The accuracy proportion to the stimulus with the visual angle 0.30° (condition 3) reached chance level at eccentricity 7° . This proportion reached chance level at eccentricity 4° in condition 4 (stimulus of size 0.15°).

The best fitting linear model for the pattern of RTs in condition 1 (stimuli of size 1.20°) was a simple linear function of $y = 368.04 + 10.561x$, $R^2 = 0.988$ [$F(8, 112) = 564.57$, $p < 0.0001$]; and in condition 2 (stimuli of size 0.60°) was again, a simple linear function of $y = 386.29 + 15.237x$, $R^2 = 0.954$ [$F(8, 112) = 603.53$, $p < 0.0001$]. As the size of stimuli became smaller, projection of the stimuli on further eccentricities led to a sharp decrease in the percentage of the correct response (Figure 23 & Table 11, Appendix B). Assuming that when accuracy decreases to the chance level the response time tends towards infinite, the general linear model in condition 3 will be $y = 449.35 - 31.701x + 15.247x^2$, $R^2 = 0.871$ [$F(8, 112) = 15.47$, $p < 0.0015$]; and in condition 4 will be $y = 495.34 - 18.272x + 19.420x^2$, $R^2 = 0.871$ [$F(8, 112) = 246.29$, $p < 0.0001$].

As Figure 22 indicates, in conditions 1 and 2, the stimuli were identified faster when they were projected to the centre of visual field than to the periphery. Generally speaking, the response time decreases as a visual image of a fixed size moves from the most peripheral locations towards fovea. However, when the visual angle of the stimuli was smaller (conditions 3 and 4), an initial decrease in the response time can be seen which does not fit with this general trend. As Figure 22 indicates the response times to the stimuli of visual angle 0.30° and 0.15° (conditions 3 and 4) decreases when the eccentricity increases from zero to 1° . This initial decrease in RTs was amended by further increase in eccentricity. This data does not seem to be incompatible with what I

found for the larger stimuli (conditions 1 and 2). At eccentricity zero the centre of the stimulus was located at the centre of the visual field, but this does not mean that stimulus properties were displayed at that location. It was only possible for the small Cs to be projected to foveal locations. Therefore, when a stimulus of size 1.2° is projected to an eccentricity of zero, its properties (the curvature of C and its opening) were not displayed at that eccentricity but they were projected to eccentricity 0.6° . Apparently when the stimulus was small (e.g., stimulus of size 0.15°), its properties were projected to a more foveal location than when it was large. Therefore, the reaction time to larger stimuli (i.e., condition 1 & 2) at eccentricity zero does not represent the real reaction time at that eccentricity. Therefore, the initial decrease in RTs for the small stimuli seems to be related to the slow transmission time in the most foveal locations which was not measured by the large stimulus.

The sustained-transient literature seems to fit well with this initial decrease in the response times. There is considerable physiological and psychophysical evidence (e.g., Breitmeyer & Ganz, 1976, 1977) suggesting that sustained visual subsystem is most sensitive to high spatial frequencies, predominates in central vision, and is processed slowly. On the other hand, the transient subsystem is most sensitive to low spatial frequencies, predominates in peripheral vision, and is processed fast. Our finding on the faster response times in conditions 1 and 2 in comparison to conditions 3 and 4, is compatible with the sustained-transient hypothesis. Large stimuli (low spatial frequency) were processed faster than smaller stimuli or high spatial frequency stimuli. However, changes in the location of a stimulus of a fixed size affected temporal frequency channels. This shows that transmission time may vary independently of spatial and temporal frequency channels by variations in the eccentricity. This explanation at this stage is speculative.

Meanwhile it has been proposed that low spatial frequencies which are associated with high resolution temporal channels are related to the processing of the global configuration, whereas higher spatial frequencies which are associated to low temporal frequencies are involved with the processing of local elements and detail (Badcock,

Whitworth, Badcock, & Lovegrove, 1990; Breitmeyer & Ganz, 1976; Kinchla, 1977). Breitmeyer (1984) proposed that as the duration of stimuli increases over about 40 msec, at a point, there will be a clear off-transient effect. However, before that point with a decrease in exposure duration of the stimulus, transient channels activated at the offset of stimulus may inhibit sustained channels. Because of the high sensitivity of transient cells to low spatial frequencies, their activation at stimulus offset may retroactively suppress the activity of high spatial frequency sustained channels and may decrease their persistence. Other studies (e.g., Hughes, 1986) proposed that activity in transient channels inhibits activity in sustained channels. Hughes indicated that choice reaction time to low spatial frequencies was not affected by the presence of high spatial frequencies. However, reaction times for high frequencies were increased by the presence of low frequencies. Hughes' study, also revealed that the type of stimulus onset (gradual versus abrupt) affected the magnitude of low spatial frequency interference. Low frequency interference increased when the stimuli were presented abruptly rather than gradually.

In the present study, the centres of four stimuli were located in one of the eccentricities from zero to 8 degrees, but since their sizes were different they were not projected exactly on those eccentricities. In the central position (eccentricity zero), in fact, the larger stimuli (1.2° and 0.6°) were projected to eccentricities 0.6° , and 0.3° , respectively while the other two small stimuli were projected to eccentricities 0.15° and 0.075° . The comparison of the pattern of responses indicated that the speed of processing of a stimulus of a constant size in eccentricities 0.075° and 0.150° was slower than the processing of the same size of stimuli in eccentricity 1° . Based on the studies on temporal and spatial frequency channels (e.g., Breitmeyer, 1975, 1984; Breitmeyer & Ganz, 1976, 1977; Lovegrove & Pepper, 1994; Weisstein, Maguire, & Brannan, 1992) it may be speculated that presentation of stimuli for a short period of time (100 msec in the present experiment) mainly activated high temporal frequency channels which were associated with low spatial frequencies. Thus, because of the activation of high temporal channels, processing of the stimuli in the centre of visual field which is more sensitive to low temporal frequency channels was slower than the peripheral locations. In other words,

because of the activation of high temporal channels speed of processing was slower in the focal most location of the visual field which is more sensitive to low temporal frequencies. As the stimulus moved from the fovea towards more peripheral areas, the density of the low spatial frequency channels increased and the condition for responding to the high temporal and low spatial frequency channels improved. However, with further increases in eccentricity, the decrease in acuity acted as a counter effect and increased the reaction time. Therefore, it seems that low temporal and high spatial channels have the highest density in the fovea. At some eccentricity around 1° (based on the results of the present Experiment) the concentration of low spatial and high temporal frequency channels reached its highest level, after which the sensitivity or density of both channels decreases. After this point, although the density of low spatial frequency channels is still higher than the other channel, the density of both channels is low.

There may be another interpretation of the results of the present study based on the inhibitory effects of the transient and sustained channels on each other. According to this interpretation although the transient system is more sensitive to motion and to flicking in the stimulus and sustained channels are sensitive to stationary stimuli, the speed of processing is not different between the two channels. However, activation of any of the channels may have an inhibitory effect on the processing of the other one. On the other hand, visual acuity decreases as a visual image moves towards more peripheral locations. In Experiment 5 exposure times of the stimuli were short, therefore, transient channels which are sensitive to motion and flicking were activated. As a result, the response time in the centre of the visual field in which sustain channels were more dense than the other locations was low. However, as the visual object moved towards periphery this inhibitory effect withers away. Therefore, response time in eccentricity 1° is faster than the fovea. However, as a general rule, by the projection of the stimulus in more peripheral locations acuity and response time decrease.

4.8 Experiment 6

In this experiment the role of size was examined when eccentricity was controlled. However, there is a limitation to the extent the size of a stimulus can be varied while keeping its eccentricity constant. Evidently a large increase in the size of a stimulus affects on its eccentricity. Therefore, only the eccentricity of the centres of stimuli can be controlled. Experiment 5 showed that variations in eccentricity did not have a consistent effect at the most foveal locations, i.e., eccentricities less than 1.00 degree. Therefore in the present study, stimuli were not displayed in the foveal locations. Only seven variations in stimulus size were made. The reaction times to stimuli of different sizes but with constant centre of eccentricity were compared with each other. The objective of this experiment was to test the size effect relatively independent of the eccentricity.

Method

Sixteen subjects participated in this experiment. The details of the method of this experiment were the same as the previous experiments except for following aspects. The stimulus was a C pointing either to the right or to the left having one of the following visual angle sizes: 0.3°, 0.6°, 0.9°, 1.2°, 1.5°, 1.8°, 2.1°. Stimuli were presented at either eccentricities of 7.15° or 2.36°. Separate blocks were allocated for each eccentricity condition. There were six experimental blocks. Three of them were allocated to the eccentricity 7.15° (condition 1) and three blocks for eccentricity 2.36° (condition 2). In fact within any experimental block eccentricity was controlled. Six experimental blocks were preceded by two practice blocks. Before, practice blocks subjects were instructed through a tutoring tour about the task and the requirements. There were 72 trials in each experimental block and 36 trials in each practice block. Each of the seven pairs of Cs was projected randomly to the highest or lowest location of one of the two eccentricity conditions. The order of the blocks was counter balanced within the subjects. Similar to the previous experiments, the task was to identify the direction of the openings of the Cs.

Results and Discussion

One subject was excluded from analysis due to his extremely high error rates. The mean reaction times and accuracy proportions for each stimulus size along each eccentricity are presented in Table 12 (Appendix B) and Figure 24. Reaction times were analysed using a five-way repeated measures ANOVA, with factors stimulus size (seven

Figure 24. Mean RTs as a function of size in Experiment 6 (Two constant eccentricities).

levels), eccentricity (two levels), direction (right or left), identity of the first fixation stimulus (x or +), and identity of the second fixation stimulus (x or +). The results revealed that larger stimuli were identified faster than smaller stimuli, $F(6, 84) = 89.55$, $p < 0.0001$. Response time was faster when subjects were directed to the location closer

to the fovea than when they were directed to a more peripheral location, $F(1, 14) = 163.91$, $p < 0.0001$. In contrast to the previous experiments, stimuli with an opening to the left were detected faster than figures with an opening to the right, in most of the size conditions and within both eccentricities. This was reflected in the significant interaction between direction and size, $F(6, 84) = 163.91$, $p < 0.0001$; and direction and eccentricity, $F(1, 14) = 163.91$, $p < 0.0001$. The interaction among eccentricity, size, and direction was also significant, $F(6, 84) = 4.03$, $p < 0.0001$. As can be seen in Figure 24, the pattern of results was not the same across eccentricities. This difference was reflected in significant interaction of eccentricity and stimulus size, the $F(6, 84) = 157.47$, $p < 0.0001$; and second order interaction of size, eccentricity, and direction, $F(6, 84) = 4.03$, $p < 0.0001$. No other main effect or the interaction of the factors were significant (Table 27, Appendix B).

A similar analysis was conducted on accuracy proportions. There was only a main effect of size, $F(1, 14) = 47.45$, $p < 0.0001$; with accuracy being higher with large stimuli than the small ones. The pattern of accuracy proportions changed according to the stimulus size across eccentricity. This was reflected in the significant interaction of eccentricity and stimulus size, $F(1, 14) = 27.70$, $p < 0.0001$. Meanwhile, this significant interaction was probably largely due to the considerably low accuracy level to the smallest stimuli in the large eccentricity condition. There was a significant interaction between eccentricity and direction, $F(1, 14) = 47.45$, $p < 0.0001$; and between size and direction, $F(6, 84) = 7.00$, $p < 0.0001$. There were no other significant interaction of interest (Table 28, Appendix B). None of the results of RT analysis can be attributed to a speed-accuracy trade-off. The average error rate to the verbal response to the identity of the second fixation stimulus was 0.01 (SD= 0.02). Since this average was low, no further analysis was conducted on it.

The results shown in Figure 24 indicated that there was a faster reaction time to the series of stimuli located at the smaller eccentricity (upper function). This finding is in line with the results of Experiment 5 on the eccentricity effect. The rate of decrease in the response time was much less than the rate of increase in stimulus size. That means that

the rate of increase in the speed of reaction time by further increase of a unit of size, decreased as the size of stimulus increased (Figure 24). The patterns of responses to the large and small eccentricities suggested a logarithmic function of $y = 476.08 * x^{-0.20250}$, $R^2 = 0.956$, for the small eccentricity condition; and a logarithmic function of $y = 391.65 * x^{-0.11294}$, $R^2 = 0.938$, for the large eccentricity condition. These equations suggested large changes in the speed of processing as a result of an increase in the size of small entities, and smaller changes in the response time as result of a change in the size of large stimuli.

General Discussion

Navon (1977) demonstrated the temporal precedence of global configurations over their local elements. However, Kinchla and Wolfe (1979) suggested that the relative speed of processing of the two levels is related to the visual angle of the global configuration. Navon and Norman (1983) attempted to study the effect of size on the speed of processing of the two levels when eccentricity was not confounded with globality. However, their study was conducted under a condition which was different from the experiment of Kinchla and Wolfe (1979). The study of Kinchla and Wolfe was conducted under size uncertainty conditions. That is stimuli with various sizes were mixed within a block in a randomised condition. Therefore, subjects were not able to attend selectively to a certain eccentricity. However, Navon and Norman's study was performed in a size certainty condition. Therefore, it may be suggested that the difference between these two studies originated from the difference in their experimental presentation conditions.

The results of the Experiments 2A, 3A, and 4A showed that the so called global advantage effect was not changed by the experimental presentation conditions (randomised versus blocked), and size/eccentricity uncertainty versus size/eccentricity certainty conditions. Therefore, it may be concluded that the global configurations of compound patterns with placeholder relationship were processed faster than their local components regardless of the experimental conditions.

The global advantage in the size certainty condition, when stimuli of a fixed size were blocked in separate blocks of random order, suggested that the global advantage was not the result of a cognitive strategy employed by the subject to attend to the more likely eccentricities in the middle of the visual field, a range effect, or the result of a particular experimental presentation condition. Experiments 2A, 3A, and 4A do not solely clarify the source and locus of the global advantage. However, the comparison of the results of these experiments with the findings of Experiments 2B, 3B, and 4B indicated that in both randomised versus blocked presentations and size uncertainty versus certainty conditions, the global or 'similar to global' figures were identified faster than the local or 'similar to local' ones. The consistency of the results of these two groups of experiments suggests that the difference in sizes of the global and local levels and/or the difference in the eccentricity of the two levels play a determinant role in the relative speed of processing of the two levels. Meanwhile when the eccentricities of the global and local levels were equated, large (i.e., global or 'similar to global') shapes were processed faster than small (i.e., local or 'similar to local') ones. The differences in the relative speeds of processing of the large and small figures were independent of their structural quality. That means in both compound and single structures large shapes with central positions were identified significantly faster than small shapes with non-central positions of the same eccentricity.

Comparison of the results of Experiments 2A, 2B, 3A, 3B, 4A, and 4B suggests that the response times to the global and 'similar to global' figures were faster in the size certainty than in the size uncertainty condition (Figures 15, 18, & 21 together). The patterns of reaction times to the large shapes in single and compound conditions suggest that there was not a significant difference between the speeds of processing of large single and large compound shapes. However there were considerable and/or significant differences among the RTs to local elements as the components of a compound shape and as single locals. In any experimental condition compound locals were detected faster than the respective single locals, beyond an eccentricity of 1.2° . However, at eccentricities less than this in the all experimental conditions single locals were detected faster than the compound locals. This may be interpreted in terms of a masking effect which might be

caused by the neighbouring figures when the compound configuration was small. As the relative size of the compound shapes increased, the masking effect disappeared. On the other hand, it seems that in larger compound shapes local components were detected faster than single locals of the same size because of the ease of the identification of any of the sixteen compound locals in any of the locations of compound shapes than the detection of just one figure at an uncertain location either in the top or in the down. However, further scrutiny of these aspects needs conducting all these experiments within one comprehensive experiment.

Meanwhile, the pattern of responses to any of the global and local figures in these three experiments suggests that the proportional enlargement of size and eccentricity of the stimulus resulted in a quadratic function of reaction times across the eccentricity. The similarity of the pattern of result to the global and local levels provides evidence that the patterns of RTs in these three experiments were not the results of presentation conditions and/ or certainty versus uncertainty of the stimuli. In fact, with increasing visual angle of a stimulus, a tendency was found towards faster processing of the stimuli about eccentricity 2.35° . The quadratic pattern of responses to the compound stimuli of Experiments 2A, 3A, and 4A and to the single stimuli of Experiments 2B, 3B, and 4B suggests that this pattern was not formed by the structural dependency of the global and local levels of a compound pattern. These findings suggest that with the proportional enlargement of either a global or local figure the speed of processing will reach a minimum as the stimuli are projected to somewhere between eccentricities 1.2° to 3.6° degrees.

To study the effect of eccentricity on the response latency, stimuli of a fixed size were projected to different eccentricities (Experiment 5). The results indicated an initial increase and then a very rapid decrease in the speed of processing with an increase in the eccentricity when stimulus size was controlled. The initial slow reaction time in the centre of visual field in comparison to an eccentricity of 1° may be tentatively interpreted as the result of a higher density of transient channels around that an eccentricity of in

comparisons to the most foveal locations which has the highest density of sustained channels. At more peripheral locations both channels are more sparse than the centre.

Experiment 6 indicated that when eccentricity was controlled, size had a 'decreasing exponential' function by reaction time. That is small changes in the size of a small stimulus make very large changes in the response time, and large changes in the size of a large stimulus produce little changes in the response time. Together, the results of Experiments 4 and 5 provide an explanation of the quadratic functions in the previous experiments. Experiment 5 indicated that when size was controlled, response time by eccentricity has an increasing linear function, whereas Experiment 6 showed that when eccentricity was controlled, response time by size formed a decreasing exponential function. These two functions clarify the nature of the quadratic functions of the series A and B experiments. If we add those two functions together when both size and eccentricity are manipulated, a quadratic function will be formed from the addition of decreasing exponential and increasing linear functions. When the size and the eccentricity of a small image displayed at the fovea are proportionally enlarged, at the foveal locations size plays a greater role and a small increase in size is associated with a large decrease in RTs. On the other hand, at the most peripheral locations, RT is more influenced by changes in the eccentricity the size. These two functions together would produce quadratic functions as found in the first six experiments of the present chapter.

As a matter of fact, the global and 'similar to global' shapes had a central position. That is, they were presented round the fixation stimulus, whereas local and 'similar to local' shapes had a non-central position. The comparison of the results of the four conditions of Experiment 5 with each other and the data on the effect of size when the eccentricity was controlled (Experiment 6) showed that patterns of RTs in Experiments 2A, 2B, 3A, 3B, 4A, and 4B were not influenced by the difference in the positions (central versus non-central) of the global and local, or 'similar to global' and 'similar to local' figures. Generally speaking, speed of processing decreases sharply as an increase in eccentricity, with the exception of the most-foveal location. That means if the sizes of two stimuli were the same, the one with more central position will be identified faster than

the one with the more peripheral position. On the other hand, the pattern of response to stimuli of a fixed eccentricity produced a decreasing exponential function of reaction times across stimulus size, and the proportional enlargement of the size and eccentricity resulted in a quadratic function of pattern of response. Therefore, it does not seem that there is anything special in the dichotomy of central versus non-central independent from size and eccentricity dimensions.

The experiments of this chapter provide evidence regarding the speed of processing of hierarchical patterns. It seems that size and eccentricity are the main determinants of the response times to the global configurations and the local components, and the weights of these effects vary across the visual field. The results provide a possible explanation for the difference between studies which indicated a turning point in the direction of global/local advantage according to the visual angle of the compound patterns (e.g., Kinchla & Wolfe, 1979; Lamb & Robertson, 1990) and the studies based on the unidirectionality of the 'global precedence hypothesis' (e.g., Navon, 1977; Navon & Norman, 1983). It seems reasonable to assume that when the local elements are fairly large and are mainly projected on the middle of the visual field at about eccentricity of 2.35° , when the stimulus is proportionally enlarged, or to an eccentricity of 1° , when the size of the compound pattern is constant, and the features of the global configuration are projected to the focal-most or peripheral-most locations, RTs to the local components may become faster than RTs to the global configuration. In the present study there was not such a point at which the minimum speed of processing of the local level preceded the maximum speed of processing of the global levels. The extreme eccentricity used in this experiment was 8.15° and the difference in sizes of the global and local figures was 1 to eight, thus, there is a possibility that if the global properties were projected to more peripheral locations than the locations used in the present study, they may be responded to slower than local elements. Meanwhile, as the difference between the sizes of a global configuration and its local components becomes smaller, the possibility that local components are identified faster than the global properties increases. The patterns of response times to the variations in size and eccentricity in the present study, and their

combined effects are compatible with such a possibility. As a general conclusion, at least at the level of the physical properties of the stimulus the response times to the global and local levels were determined by the relative size and eccentricity of the global configuration and local elements.

The results reported in this chapter also indicated that the interaction of size and eccentricity produces a quadratic function for RT patterns when size and eccentricity are proportionally enlarged. There were some slight variations in the speed of response according to the task demand, however, the general trend of the identification of large focal features faster than small peripheral ones, and the general pattern of the U-shaped response latency functioning according to the proportional enlargement of the size and eccentricity of the stimuli did not change. Second, faster speed of response to the stimuli projected to eccentricity 1° in comparison to the foveal images suggested the possible involvement of transient and sustained channels. Finally, the study of pattern of responses to the right and left visual fields in the series of experiments reported in this chapter indicated a variation in visual field advantage across eccentricity, size, and experiments. Variation in superiority of the right or left visual field across the experiments and the comparison of this variation with the finding of Experiment 1, and the existing controversy in the literature suggests that association between global/local processing and hemispheric asymmetry is premature and need more detailed examination.

Before closing this chapter some clarifications should be made regarding the mask stimulus: Global advantage has been found in many of the experiments reported in the literature that have not used mask stimuli. Therefore, it does not seem reasonable to attribute the global advantage found in this chapter to the effect of the mask stimulus used here. As was already mentioned Navon and Norman (1983) conducted experiments with stimuli similar to the ones used in the experiments of this chapter, without using a mask stimulus, and found a global advantage effect. Meanwhile, similarity of patterns of responses (i.e., quadratic functions) to the global and local levels in Experiments 2A, 2B, 3A, 3B, 4A, and 4B suggests that the difference in spatial properties of mask elements and test stimuli was not the determinant of these patterns. Although there was a distinct

difference between sizes of the global and local levels and as a result in their spatial frequency structure, both of them showed the same pattern of responses. It seems that if these quadratic functions were formed by variations in relative spatial properties of the mask and test stimuli, they should not be the same for the global and local levels.

Also variations in RTs across eccentricity in Experiment 5 cannot be attributed to variations in relative spatial properties of the test and mask stimuli, because there was no change in these properties within each experimental condition. In Experiment 6 although the relative sizes of the test and mask stimuli did not change across two experimental conditions, two separate functions were obtained for two eccentricity conditions. This shift in RT functions can be attributed to eccentricity, and the decrease in RTs can be attributed to the decrease in size of the stimulus rather than the interaction of the mask and the test stimulus. Therefore, the mask stimulus cannot account for any of the results reported in this chapter.

The findings of the present study not only clarify some ambiguities in the "global precedence paradigm," but also provide an opportunity to compare the global precedence paradigm with other hypothesis, such as the outside/inside effect. The review of literature on the speed of processing of outside/inside shapes indicates a faster reaction time in favour of outside properties (Earhard, 1990; Earhard & Walker, 1985). This finding may be interpreted in terms of the proposed global precedence effect in the literature. It seems possible that the higher speeds of processing of out-side in comparison to inside properties and global configurations in contrast to local elements are directed and or influenced by a common mechanism. In fact, outside features may be processed faster than or before inside properties because their sizes are larger than the inside properties and/ or their location in the eccentricity function is closer to the minimum point than to the inside features.

Chapter 5

Do the Global Advantage and Interference Effects Co-vary?

The so called global precedence hypothesis has been studied using at least two major performance measures: the relative speed of identification and by asymmetric interference. Interference studies often produce two effects: Stroop and Garner. In a Stroop-type task the subject responds to the relevant structural component while attempting to ignore an incongruous property that was assigned to an incompatible response, whereas in a Garner task subjects are required to ignore an irrelevant property that varies unpredictably from trial to trial. That is Stroop interference arises from the content of an incongruous component, but Garner interference originates from variations on irrelevant property across trials (Pomerantz, Pristach, & Carson, 1989). The asymmetric interference found in the global precedence studies is usually a form of a Stroop effect. The question of whether performance measures such as global/local advantage and interference represent to the same theoretical account is an important issue in the study of the global precedence effect. The present chapter was planned to study the dissociation between these two measures.

Global and Local Interference and Spatial Frequency Channels

Navon (1977, Experiments 1 & 2) demonstrated that the response to an auditorially presented name of a letter was interfered by the global level and not by the local level of a visually presented stimulus. Using a Stroop-type task, Navon (1977, Experiment 3) also found that reaction times to the attended local level were influenced by the identity of the unattended global level, but not vice versa.

Navon (1977, 1981b) proposed that the locus of global precedence is probably based on the faster speed of transmission in the low spatial frequency channels that are

the carriers of global information, in contrast to the high spatial frequency channels (e.g., Breitmeyer, 1975; Breitmeyer & Ganz, 1976) which transmit local information. According to this view asymmetric interference in favour of the global level seems to be related to the faster availability of the global information. This interpretation has been the subject of a number of studies (e.g., Antes & Mann, 1984; Badcock, Whitworth, Badcock, & Lovegrove, 1990; Shulman, Sullivan, Gish, & Sakoda, 1986). For example, Badcock, Whitworth, Badcock, and Lovegrove found that the 'consistency effect' was lost after selective removal of low spatial frequencies. Two alternative explanations for the absence of a 'consistency effect' was suggested by these workers. According to the first explanation, a failure to obtain the 'consistency effect' may be attributed to the removal of an inhibitory effect of low spatial frequencies on the inconsistent target. They argued that this view did not provide a full explanation of their data, because the removal of low-spatial frequencies would not be expected to affect the consistent target level either. Another explanation for the failure to find a consistency effect which is emphasised by these workers is based on the notion of response competition. According to this model the faster transmission of information within the low-spatial channels that results in faster processing of the global information produces a response priming which facilitates the perception of the local components when the global and local levels are consistent, and interferes with the perception of the inconsistent local level. Therefore, filtering low-spatial frequencies eliminates the consistency effect. This suggests that the global precedence and consistency effects may reflect different processes.

Dissociation of the Global Advantage and Interference Effects

The global precedence hypothesis is operationally defined as the interference of the global information in the processing of the local information, or faster and/or earlier processing of the global properties in comparison to the local properties. The idea behind this hypothesis was that the RT advantage and asymmetric interference reflect the order of processing of global and local information. However, as Lamb and Robertson (1989)

argued, if the RT advantage and interference effects reflect the order of processing, they must co-vary in a systematic way. That means global precedence should be associated with global advantage and interference and local precedence has to be associated with local advantage and interference. However, several studies have shown dissociation of the RT advantage and interference data (e.g., Lamb & Robertson, 1988; Lamb, Robertson, & Knight, 1989; Navon & Norman, 1983).

To study the possible co-variation of the global/local advantage and interference effects Lamb and Robertson (1989) conducted an experiment with large letters made up of small letters. The task was identification of a target letter either at the global or local level. Although the interference effect is usually measured within 'selective attention' conditions, a 'divided attention' strategy was used in their experiment. In a 'selective attention' condition subjects are required to attend to either the global or local level, while the unattended level has an identity similar to or different from the identity of the attended level. However, in Lamb and Robertson's experiment, attention conditions of both levels were relevant. Consistency was manipulated by the degree of the similarity relationships between the target and distractor stimuli. Therefore, the interference was measurable as the interaction between the target and distractor letters. Meanwhile, to produce variations in RT advantage, Lamb and Robertson (1989) varied the visual angle of the stimuli (See, Kinchla & Wolfe, 1979). Subjects were not required to fixate, therefore, there was no control on eye movements. Stimuli were projected to the centre of the display screen for 1 second. There were four visual angle conditions of the compound pattern, 3, 6, 9, and 12 degrees. The results demonstrated that global distractors interfered with local processing, while there was, if any, a local RT advantage. The results of the experiment of Lamb and Robertson's (1989) study indicated that RT does not always co-vary with asymmetric interference. Meanwhile, these workers suggested that unilateral temporal lobe lesions can eliminate interference effects while keeping RT advantage intact. From this, they concluded that interference does not simply reflect the order or the relative speed of processing of the global and local levels. Based on the psychoneurological findings, they suggested that RT advantage and interference may be determined by separate

mechanisms. However, global/local advantage and interference may be influenced by task demands and physical properties of the stimulus such as size and eccentricity.

Task Requirement, Stimuli-Type, and Interference Effect

Some studies have found bi-directionality in the interference effect measured by RTs to the consistent and inconsistent global and local levels. For example, Luna, Merino, and Marcos-Ruiz (1990) proposed that the interference which was measured by RTs for consistent and inconsistent conditions, can occur in both global and local levels, although the interference caused by the unattended global configuration on the local level was stronger than the interference originated from the unattended local elements on the global level. Some other studies (Kimchi, 1989, 1992; Pomerantz & Sager, 1975) indicated that the consistency effect is not always global-to-local, and it varies according to the task requirement and type of stimulus. For example, Kimchi (1992) suggested that asymmetric interference depends on the number of elements of the compound pattern. Kimchi proposed that in few-element stimuli in which global configuration and figural components are perceptually integral, the interference between the two levels is stronger than with the many-element stimuli, in which global configuration and textural elements are more separable. In an experiment conducted by Kimchi (1989) with few- and many-element squares and rectangles made up of either rectangles or squares, global dominance was found with the many-element patterns in a same-different task, only when the incompatibility was in the irrelevant dimension. With few-element patterns global interference was obtained when the two levels were consistent, and mutual interference in the inconsistent "same" trials, with some global advantage were obtained.

The result of a study by Wandmacher and Arend (1985) with stimuli similar to the ones used by Pomerantz (1983, triangles and arrows) indicated only a negligible Stroop-type interference by both irrelevant global and local levels. According to these workers, the global advantage appears not to be associated with an inevitable Stroop-type interference in Type-N stimulus. They believe that the Stroop-type interference emerges

"whenever a given task allows or requires for selecting and utilising a global feature for determining the response" (Wandmacher & Arend, 1984, p.156).

Regardless of the order of processing, whether the global/local advantage and the global/local asymmetric interference, originate from a common mechanism is a controversial problem. However, it seems more probable that response competition has its origin in 'global precedence' rather than being its source (Hughes, 1984). Meanwhile, it should be considered that the temporal precedence or asymmetric interference does not determine if these effects are simply because of the earlier availability of information at the superior level or if that information is partly or fully used as an output to process information at the level completed later (Lasaga & Hecht, 1991). Task requirement will not be experimentally investigated in this chapter but it is explained as an issue that may effect experimental results.

Goodness of the Shape and Global/Local Interference

Goodness of a form and the facilitation which it may provide for information processing is a concept basic to the principles of Gestalt psychology (LaGasse, 1993). Some workers proposed that global or local advantage depends on the quality (goodness) of the global and local figures (e.g., Kimchi, 1992; Lasaga & Hecht, 1991; Sebrechts & Fragala, 1985). For example, Sebrechts and Fragala (1985) found that in a same-different paradigm goodness of the unattended level interferes with the perception of the attended level. Their results suggested that a good pattern at either the global or local level detracts attention from the attended level. Lasaga and Hecht (1991) suggested that the location of local components can be identified better with structurally redundant stimuli (good patterns) than with poor shapes. Thus, according to these workers, identification of the location of either the global or local level may interfere with the processing of the other level depending on the goodness of the level. It seems that the suggestion of these workers relies on the assumption that the identification of conjunctions involves serial processing while the identification of individual features may occur in parallel. Therefore, the extent of the interfere effect may depend on the type of the relationship between the

global and local levels. For example, in a compound pattern with placeholder relationship there may be the least amount of interference by local components on the global configuration, whereas the levels of a compound pattern with featural relationship may have more mutual interference on each other. This view seems to be supported by the results of the experiments of the previous chapter of the present study, where the reaction times to the global and local levels were equal or slightly faster than RTs to the single presentation of stimuli of the same size as any of the global or local figures.

This view has been supported by some other workers. For example, LaGasse (1993), Treisman (1982), and Ward (1982) proposed that all the features of a form are processed in parallel, with approximately the equal processing time and without the need for focal attention. Then, these separately extracted conjoin into a perceptual view by allocation of attention to a particular spatial location. This means that the arbitrary conjunction of features is a serial process, and depends on the goodness of features. Ward (1982) suggested that the global precedence is at the level of conjoining features into a visual object. His model demonstrated that more conspicuous features are processed faster than less good or less conspicuous features. Therefore, the order of processing, according to this worker, may be either global-to-local or local-to-global. Due to this view, asymmetric interference can be interpreted as being related to the goodness of the shapes of any of the two structural levels. Therefore, the model did not necessarily predict a global/local advantage or asymmetric interference of a fixed direction. The precedence of any of the two levels or the magnitude of its interference on the processing of the other level depends on the conspicuousness of that level which is determined by the goodness of the shape. Therefore, the model predicts the global or local advantage, and the global or local asymmetric interference, depending on the quality of any of the structural levels. The question of goodness of goodness of a shape is not experimentally investigated in this chapter but it is discussed as an issue that requires further experimentation.

Size of the Stimulus and the Interference Effect

Kinchla and Wolfe (1979) suggested that there is a reversal in the temporal order of processing of the global and local levels with eccentricity. However, their study failed to examine the effect of the size of the stimulus on the consistency/inconsistency of the levels. Navon and Norman (1983, Experiment 2) studied this effect using stimuli with all their elements located along their perimeters. Applying a 'selective attention' condition, subjects were required to identify left- or right-facing large Cs made up of either left- or right-facing small Cs. The stimuli were presented in two visual angle conditions: small (2°) and large (17.25°). The results of this experiment demonstrated that in the small visual angle condition the global level interfered with the processing of the local elements, but not vice versa. However, for the large visual angle condition, the interference effect was smaller and symmetrical. The symmetrical interference/facilitation in the latter condition suggested that there might be a limit or borderline in the visual angle size of the local figure beyond which an increase in the size of that figure the asymmetric interference of the unattended global figures was lapsed. It means that, when the relative salience of the local level increased, the global level failed to maintain greater interference on the local components. In fact, small local elements were more easily ignored and were less susceptible to the interference. Navon and Norman's study did not provide more details on the nature of asymmetric interference.

Antes and Mann (1984) conducted an experiment which was inspired by the Kinchla and Wolfe's view on the existence of a reversal in the temporal order of processing of the global and local levels. Stimuli were line drawings of natural scenes. Antes and Mann (1984) found that the consistency of the global and local levels was less important for large scenes when the subjects' attention was directed locally than globally, whereas the inconsistency of the levels did not produce an interference on the processing of the local elements on locally directed trials, the opposite was found for the small scenes. That is the global forms were processed more rapidly and were not affected by local elements when the attention was directed globally. Antes and Mann interpreted this result as the preference of the perceptual organisation for an optimum bandwidth of

spatial frequency (or size). According to these workers the spatial frequency of any of the global or local stimuli which falls within that critical bandwidth will be processed faster and will have stronger interference on the other level. Clearly in terms of the results of Chapter 4, a comprehensive explanation of the interference effect must address not only the role of size but also the eccentricity as a factor closely related to the size.

Eccentricity

It appears that the nature of the relationship between eccentricity and the global precedence effect has not been fully studied. There are only some suggestions that the global advantage may be affected by the variations in eccentricity (e.g., Lamb & Robertson, 1989; Luna, Merino, & Marcos-Ruiz, 1990; Navon & Norman, 1983). As was mentioned in the previous chapter with the exception of Navon and Norman's study, others have not manipulated eccentricity directly. Based on what has been suggested within the global precedence literature, there are two main interpretations about the role of eccentricity on the processing of the global and local levels. According to the first interpretation, the pattern of responses across the eccentricity is regulated by directed and/or reflexive attentional factors, such as range effect (Humphreys, 1981; LaBerge, 1983, LaBerge & Brown, 1986). For example, LaBerge and Brown (1986) suggested that attentional and not sensitivity factors dominate the processing of visual targets. That is the decrease of acuity at peripheral locations plays a minor role, if any. These workers argued that narrowing the range of expectation for a target (decreasing the possible range of visual field or eccentricity) does not necessarily result in a faster response to that target. In a study conducted by these researchers subjects were required to identify a target embedded in a pair of vertical lines. The target was displayed in one of five locations within a particular horizontal range. There were five locations, from 1.7° to 8.6°. The pattern of RTs to the target exhibited a V-shape curve, with the lowest RT to the initial point of attention. The response times at the extreme locations of the five ranges showed no significant increase with eccentricity. These results indicated that the influence of variations in eccentricity is negligible, in comparison to attentional factors.

According to the second interpretation visual acuity decreases as the result of an increase in the eccentricity (Navon & Norman, 1983). The decrease in acuity may be interpreted as the result of a decrease in the density of cone receptors at the peripheral locations (Yellott, Wandell, & Cornsweet, 1984). For example, Polyak (1957) found that the density of cones at a location 5° from the fovea is about 1/10 of that at foveal location, where the receptor density is maximum (Osterberg, 1935). The controversy in the interpretation of the role of eccentricity necessitates a comprehensive study on the role of eccentricity in the processing of the global and local levels. The results of experiments reported in the previous chapter showed that attentional factors are not determinants of patterns of responses obtained in these experiments. However, these experiments were conducted with stimuli which their global and local levels had a neutral relationship with each other. Therefore, there is still a need for further confirmation of the results obtained in the previous chapter with stimuli that their attended and unattended levels are consistent or conflicting with each other.

5.1 Experiment 7

In the previous chapter of this thesis it was shown that size and eccentricity are likely determinants of the global advantage (the global advantage refers to the faster identification of the global level in comparison to the local components). The collation of the latency data to the global and local levels, and 'similar to global' and 'similar to local' figures of Experiments 2A to 4B of the previous chapter, rejected the possibility of the serial processing of the global and local information. That means if there was a preference in the perceptual system to process the information in any of the global or local levels serially, or if there was any interference from any of the levels on the RTs to the identification of the other level, the response times to the 'similar to global' or 'similar to local' stimuli would be respectively faster than the response times to the global and local levels. However, this was not the case. Reaction times to the global figures were either non-significantly different or a bit faster than the 'similar to global' figures, and RTs to the local figures were mostly faster than the 'similar to local' shapes, except for the two

smallest size/eccentricity conditions. This exception was interpreted as the possible joint effect of masking produced by the adjacent local elements and uncertainty in the location of the 'similar to local' stimulus.

These findings also suggest that the processing of the global or local information was not interfered with by the information of the other level when their identities were neutral to each other. Therefore, judging from the results of the previous chapter, it seems likely that either the global or local information can be processed in parallel, at a preattentive level, and when there is no congruity or discongruity between the identities of the two levels, none of them interferes with the processing of the other level. However, it may be argued that when the identities of the two levels are neutral to each other, the irrelevant level can be easily ignored, because it contains no response-associated information (Navon & Norman, 1983). It seems that the possible intervention of the any of the levels on the other would be stronger if a Stroop-type stimulus was used. In such a condition, the intervention of the identity of the irrelevant level may be used as the measure for the precedence of that level.

In the previous sections of the present chapter it was shown that there is a controversy in the literature about whether the global/local advantage and interference effects are the same or different mechanisms. Meanwhile it was indicated that there is a confusion in the literature whether the interference effect is symmetrical or asymmetrical. In addition, the effect of the interaction between eccentricity and size has not been studied on global/local interference. To answer these questions and to clarify the existing controversy, the present experiment was designed to fulfil the following purposes. First, to test the interference effect according to the variations in size/eccentricity, using the stimulus in which the eccentricities of the two levels were equated. Second, to determine the pattern of responses to the global and local levels in a size uncertainty condition when the attended and unattended levels were consistent or conflicting with each other.

Method

Subjects

Seventeen right-handed undergraduate students at the University of Wollongong served as subjects. Each subject attended in a single experimental session of 50-60 minutes. They received either money or some course credit in return for their participation. All reported normal or corrected to normal vision.

Apparatus and Stimuli

Stimulus presentation and data collection were controlled by an IBM AH compatible computer with a VGA monitor. The RT resolution of the software was 1 msec, and the refreshment rate was 16 msec. The monitor had a matrix size of 640 x 480 pixels. Each pixel was associated with an image of 0.37 mm in length and 0.39 mm in width of the monitor. The stimuli were left- or right-facing large Cs consisting of left- or right-facing small Cs (Figure 25). They were made of number of pixels per element. There were 13 small Cs in the perimeter of any of the large Cs. The size of the opening of any of the global or local figure was 72° out of its perimeter. There were nine size/eccentricity visual angles. The global configurations each had one of the following visual angle sizes: 0.5°, 1.1°, 2.4°, 4.7°, 7.2°, 9.6°, 12.0°, 14.3°, and 16.3°.

Figure 25. The set of stimuli used in Experiment 7.

Since the stimuli were circular figures around the fixation point, the eccentricity of each of them was equal to half the visual angle of the diameter (or size) of the global

configuration. The size of any of the local elements was about one eighth of the global configuration they belonged to. Any of the stimuli illustrated in Figure 25 had equal chance of being displayed with any of the above mentioned sizes. The experiment was conducted in a darkened room. The luminance of the monitor was decreased, not to hurt the subjects' eyes and to decrease the after image effect. The test, mask, and fixation stimuli were white on a black background, giving a very high contrast. The luminance of all stimulus events was approximately 2 cd/m².

Procedure

The stimulus displays were viewed from a distance of 60 cm, while the subjects' head was stabilised in a chin rest. Viewing was binocular. The task was to identify the direction of the opening of a C either at the global or local level. The index fingers of the right and left hands were assigned for the right- and left- facing targets, respectively. Each subject performed in a single session consisting of a tutoring tour, and 2 practice and 4 experimental blocks. There were 36 trials in each practice and 108 trials in each experimental block. One practice and 2 experimental blocks were assigned to the global response, and one practice and two experimental blocks were assigned to the local response. The results of the practice trials were not included in the analysis. The order of the practice and experimental blocks was counter balanced across subjects.

A trial started with the first fixation stimulus appearing in the centre of the screen. The first fixation stimulus was either an "x" or a "+", measuring a visual angle of about 0.05°. Subjects were required to press a specially marked key with the index finger of the right hand if the first fixation stimulus was a plus, and another specially marked key with the index finger of the left hand if it was an "x." After the subject's response with either the right or left index finger, the first fixation stimuli disappeared and immediately after that the test stimulus was displayed for 100 msec. Concurrent with the test stimulus, again, another "x" or "+" of the same size as the first fixation stimulus was displayed in the centre of screen, as the second fixation stimulus. The duration of the second fixation stimulus was as long as the test stimulus duration. The identities of the first and second

fixation stimuli were randomly assigned by the computer. Therefore, they might be the same or different from each other. Subjects were required to notice the identity of the second fixation stimulus and were verbally questioned in about 15 percent of randomly selected trials. Similar to the experiments in chapter 2, the idea behind assigning the first and second fixation stimuli was to force the subjects to fixate at the fixation point all the time, and to prevent the possible eye movements. The test stimulus was followed by a mask similar to the one was used in the experiments reported in chapter 4. The mask disappeared after the response or after the a time-out of 2000 msec. Only incorrect responses were followed by auditory feedback. The next trial started 1000 msec later with the first fixation point appearing on the screen. The subjects were required to respond as fast as possible but to avoid errors. The response times and accuracy rates to the test stimuli and the accuracy rates to the verbal responses to the second fixation stimuli were recorded.

Results

One subject was excluded from the analysis due to her extremely high error rates. Because of the limitation of the statistical package with regard to the segmentation of the cells of the data ($2 \times 2 \times 9 \times 2 \times 2 \times 2 = 288$ conditions), it was not possible to study all variables involved within one analysis. Therefore, two separate repeated measures ANOVAs were conducted for RT analysis. A two-way repeated measures ANOVA was performed for the analysis of reaction times to the first (x or +) and second fixation stimuli (x or +). No significant main effects and interaction were found between the factors. The data entered the analysis and graphed were derived from means of the subject's means. Since the results of the experiments of the previous chapter did not show any significant interaction between the identities of the first and the second fixation stimulus and the other factors, no further analysis was conducted on these two factors.

Average correct RTs, accuracy rates, and respective standard deviations were grouped and illustrated according to target level, eccentricity, and consistency in Table 29 (Appendix C) and Figure 26. The mean correct response times per subjects, eccentricity

condition (9 conditions), target level (global or local), consistency of the levels (consistent or inconsistent), and the direction of the opening of the target level (right or left) were analysed by a four way repeated measure analysis of variance, with eccentricity, target level, consistency, and direction as the within group independent variables and RT as the dependent variable. Analysis of variance revealed that the global configuration was identified faster than the local components, $F(1, 15) = 1061.42$, $P < 0.0001$. The response times to both global and local levels varied across eccentricity.

Figure 26. Mean RTs as a function of target level and eccentricity in Experiment 7.

This was reflected in the significant main effect of eccentricity, $F(8, 120) = 169.62$, $P < 0.0001$; and the significant interaction of eccentricity and target level, $F(8, 120) = 79.75$, $P < 0.0001$. This shows that the pattern for global across eccentricity was different from that local. Further analysis was conducted to obtain the general linear model of the pattern of responses to the global and local level across eccentricity. The results showed that the pattern of responses to the global, $F(8, 120) = 183.84$, $P < 0.0001$; and local,

$F(8, 120) = 1536.42$, $P < 0.0001$, levels were best fitted with a quadratic function (Figure 26).

Although there was not an overall significant effect of consistency, the significant interactions of eccentricity X consistency, $F(8, 120) = 10.42$, $P < 0.0001$; and target level X eccentricity X consistency, $F(8, 120) = 4.45$, $P < 0.0001$; suggested that the effect of consistency varied across eccentricity and target level (Figure 27). In eccentricities 0.25° , 0.6° , and 1.2° , the attended local elements consistent with the unattended global configurations were identified 74, 18 and 14 msec faster than the attended local elements

Figure 27. Mean RTs as a function of target level, eccentricity, and consistency in Experiment 7.

inconsistent with the global configurations, respectively. In eccentricity 2.35° reaction times to the consistent and inconsistent local levels were close to each other. However, with further increase in the size/eccentricity of the stimulus the effect of consistency/inconsistency of the unattended global configuration on the attended local level was reversed. This time, the inconsistent local elements were detected faster than the

consistent ones. In eccentricities 3.60°, 4.80°, 6.00°, 7.15°, and 8.15° these figures were 7, 3, 8, 9, and 46 msec, respectively. On the other hand, consistency did not have a continuous and predictable effect on the identification of the global level. With eccentricities 0.25° and 4.80° global figures that were consistent with the local levels were detected slightly faster than those that were inconsistent, whereas in eccentricities 0.6° and 8.15° global figures that were inconsistent with the local figures were detected faster than the consistent ones. The reaction times to the consistent and inconsistent global figures were almost the same in other eccentricities.

Although no significant main effect of direction of the opening of the target level was found, consistent figures with an opening to the left were identified faster than the consistent letters with an opening to the right. However, there was not such a difference concerning the direction of opening of the inconsistent figures. This difference was reflected in the significant interaction between direction and consistency, $F(1, 15) = 4.51$, $P < 0.0406$. The only other significant interaction was between eccentricity and direction, $F(8, 120) = 2.40$, $P < 0.0160$, which indicated the variations in response times with regard to the direction of the opening of the stimulus across eccentricity.

The overall accuracy proportions were fairly high, 1.00 (SD = 1.00) to the global, and 0.98 (SD = 0.15) to the local levels (Table 29, Appendix C). However, because of high variations in accuracy proportions further analysis was conducted on them. A four-way repeated measures ANOVA similar to RT analysis was employed. Three out of four main effects were significant: target level, $F(1, 15) = 50.01$, $P < 0.0001$; eccentricity, $F(8, 120) = 16.84$, $P < 0.0001$; and consistency, $F(1, 15) = 14.17$, $P < 0.0003$. There was not any significant difference between the accuracy rates to the consistent and inconsistent global figures across eccentricity, however there was a tendency in the consistent local levels displayed in small eccentricities to be processed more accurately than the inconsistent locals. This trend was reversed in large eccentricity conditions. These were reflected in the significant interactions of target level and consistency, $F(1, 15) = 17.21$, $P < 0.0001$; eccentricity and consistency, $F(8, 120) = 9.52$, $P < 0.0001$; eccentricity and target level, $F(8, 120) = 17.73$, $P < 0.0001$; and target level, consistency,

and eccentricity, $F(8, 120) = 11.90$, $P < 0.0061$. There were not any other significant interaction of interest in both RT and accuracy analyses. Since all subjects achieved a high degree of accuracy, 0.99 (SD = 0.01), in their verbal responses to second fixation stimuli no further analysis was carried on it. The comparison of the results of latency and accuracy analysis indicated that none of the findings of RT analysis can be attributed to a speed-accuracy trade-off.

Discussion

Global Advantage

The present study failed to find a relationship between retinal size and global advantage in a sense proposed by some workers (e.g., Antes & Mann, 1984; Kinchla & Wolfe, 1979; Lamb & Robertson, 1989). Using the stimulus with either inconsistent or consistent levels it was found that in size/eccentricity uncertainty condition, the global level was identified faster than the local level across all size/eccentricity conditions. The use of response-associated stimuli did not change the pattern of response suggested by the findings of the previous chapter. This provided the evidence that the findings with neutral stimuli were generalisable to conflicting/consistent stimuli.

As the size of stimuli increased, response times to both the global and local levels decreased, up to a certain size/eccentricity. Beyond this, further increase in stimulus size increased the response times to both levels. The findings of the previous chapter suggested the possibility of an optimum retinal location where the images of either the global and local levels were processed faster than the other locations, when the size/eccentricity of the stimulus is proportionally enlarged. The present experiment broadly replicates that finding but also shows that these functions differ slightly for global and local patterns. This may be produced by the difference in the types of the stimulus in these two studies. These results in company with the findings of the previous chapter indicate that the global advantage is mainly due to the difference in the size and eccentricity of the global and local levels.

Consistency Effect

Generally it appears that with the exception of Navon and Norman's experiment (1983, Experiment 2), all other studies confounded the interference effect and eccentricity. The present experiment not only separated these factors, but also is probably the only study that examined interference effect over a wide range of size/eccentricity. Comparison of the interference produced by the unattended global level on the identification of the local level and vice versa, indicated that the absolute magnitude of interference of the unattended level was slightly higher on the local level than the global (Table 29, Appendix C), but no significant global/local interference was shown. The results demonstrated that the variation in size/eccentricity did not produce a distinct pattern of responses according to the consistency at the global level. On the other hand, although local components were influenced by the identity of the unattended global level, the direction of this effect changed with manipulation of size/eccentricity (Figure 27). The initially faster reaction times to the consistent locals were replaced by the faster responses to the inconsistent locals at large eccentricities. That is RTs to small local elements displayed at small eccentricities were decreased with the consistent identity of the unattended global level, but RTs to large local components displayed at large eccentricities were increased with unattended consistent global configuration.

Perhaps, the most important aim of the present experiment was to examine the effect of consistency across variations in size/eccentricity. As was mentioned, Navon's (1977) initial global precedence hypothesis was based on the joint occurrence of the faster response to the global configuration than the local elements, and the interference of the global distractors while attending to the local level. There are however, some major inconsistencies in the literature regarding the generalisability of these two effects. Later studies (e.g., Lamb & Robertson, 1988; Robertson & Lamb, 1991) suggested that large changes in RT advantage can occur without corresponding changes in the interference of the global level on the local elements. For example, Robertson & Lamb (1991) proposed that global interference is not related to global temporal advantage in both normal individuals and patients with lesions in right or left hemisphere.

Navon and Norman (1983) suggested a two stage model of the global precedence. The first stage of the model produces a global temporal advantage and the second stage provides the degree of interference. Navon and Norman (1983, Experiment 2) used stimuli similar to the stimuli of the present experiment. However, they had only two visual angle conditions, and they employed size/eccentricity certainty conditions. Each subject participated in two sessions, one for each visual angle condition. The results of that experiment suggested that the global level of the small visual angle condition interfered with the processing of the local level, but not vice versa. On the other hand, in the large visual angle condition the interference effect was smaller and symmetrical. Since in Navon and Norman's experiment the relative size (proportion of sizes) of the global and local level was held constant, the lack of asymmetric interference in the large visual angle condition may be related to the existence of a minimal size/eccentricity level beyond which, asymmetric interference disappears. According to this view very small local features can be ignored when they are unattended, and they are least immune to interference of the identity of the global level.

However, one of the earliest studies on asymmetric interference (Pomerantz & Sager, 1975), indicated that the interference of local elements while classifying by the global configuration was harder to be ignored than the interference caused by the irrelevant variation of the global configuration while classifying by local components. Although Pomerantz and Sager found interference effects in both directions, the magnitude of this interference was more in favour of the local elements than the global configuration. Similar results were reported by few-element stimulus (Kimchi, 1988, 1992).

Perhaps, the most important finding of the present experiment was that there was a discontinuity in the consistency effect across eccentricity. Comparison of the patterns of responses to the consistent and inconsistent stimuli at the global and local levels of the present study and other studies in the literature (some of them were already cited) suggested that the global advantage effect is not always associated with a Stroop-type interference. More specifically, with compound patterns of placeholder relationship which

were used in the present experiment, serious variations in the interference effect were observed with manipulation of size and eccentricity. Unattended local level did not show a distinct pattern of interference on the global level across size/eccentricity. However, a reversal was observed in direction of interference of the global configuration on the local level according to the size/eccentricity of the compound pattern. Experiment 1 of the present research provided some evidence on the effect of manipulation in the relative size of the global and local levels on global/local interference. It was indicated that the increase in the relative size of the local level is associated with the interference of the unattended local level on the attended global components. Comparison of the results of Experiments 1 and 7 highlights the possible effect of size and eccentricity in global/local interference.

Apart from equalisation of the eccentricities of the global and local levels in the present experiment and Navon and Norman's study, there is a sizeable difference in the type of the stimulus used in these two studies and the stimuli used by other workers. In the present experiment subjects were required to respond to the global or local levels of right- or left-facing Cs by pressing specially marked keys with the index fingers of the right or left hands. In the previous chapter it was mentioned that I found it very destructive to counter-balance key-response assignment in the pilot study. It seems that response selection in this type of task is closely related to the left-right orientation and requires less cognitive load than any other stimulus which has not any normal redundancy (correlation) with left-right orientation (Nicoletti & Umiltà, 1985). For example, the identity of the letters H or S is not associated with the right or left orientation. As a result the identities of a compound stimulus which are constituted from any of these letters may be much influenced by the identity of the other letter than a C with an opening to the right or to the left. That means responding to the stimulus that is strongly related to the left and right orientation probably needs less linguistic and attentional load than a letter, and the former is much influenced by sensory factors and less affected by attentional factors than the latter. Therefore, it is possible that the variations in the interference effect across the target levels and eccentricity were due to the type of stimulus which was used in the present experiment.

In conclusion, the present work should be considered as the reminder of the difficulty in attributing findings of temporal global/local precedence to asymmetric interference hypothesis. Although it is tempting to generalise the results of the Experiment 7, these are simply not sufficient. Compare for example, the results of this experiment with Navon and Norman's findings. Although the results of the small visual angle condition (eccentricity 1°) of Navon and Norman's Experiment were the same as the nearest eccentricity in the present experiment (eccentricity 1.2°), their results demonstrated facilitation in RTs to the consistent condition for both global and local levels at eccentricity 8.5° . The results of the present study, however, showed that the reaction times to both global and local levels at eccentricity 8.15° in inconsistent condition were faster than the consistent condition. Therefore, the present results raised the view that interference is not a continuous effect across size/eccentricity. Without further studies to show the source of the divergencies in the results of the present experiment and between these results and other studies, including the experiments discussed in Chapter 3, the present findings cannot be interpreted as firm conclusions. However, the present experiment is the first study which examined the consistency effect across a wide range of size/eccentricity condition, and it suggests that the temporal global advantage and the consistency effect, are probably independent effects.

Chapter 6

Types of the Global-Local Relationship and Outside-In Processing

How are visual objects perceived? Are they analysed in parts, or they are perceived as wholes? In any case what are the perceptual equivalents of the whole and part? For example, when we look at a map of the U.K., do we perceptually need to recognise Scotland, Wales, England, and Northern Island, to identify the U.K., or does the perception of the U.K. as a whole precede the perception of the Kingdoms? Are the same perceptual rules applied for the recognition of England when it is embedded within a map of the Europe? Is the perceptual relationship between the identification of the maps of the Kingdoms and the U.K. the same as the relationship between the percepts of the United Kingdom and the Europe? Are these perceptual relationships the same as the relationship between the percepts of eyes or nose within a configuration of a face, or the relation between the directions of two parentheses and the perception of an emerged closure made from these parentheses? As was discussed in Chapter 1, the relationship between physical and perceptual properties of the stimulus is an important issue in the study of visual perception.

Controversy in the Data and Conceptualisation

It seems that at least part of the inconsistency and confusion in the literature regarding the global precedence hypothesis originates from the inconsistency in the definition of the concepts such as whole, part, global, and local, perceptual reality of these concepts, and their correspondence with the physical structure of the stimulus? For example, what are the global and local levels of a map of Australia. Are the figures of Australian states the perceptual parts of a map of Australia? Is the perceptual relationship between the latter percepts the same as the relationship between the components of a face and a face as a global configuration?

The global precedence hypothesis assumes that every stimulus has potentially several levels of complexity, which are not structurally equivalent. As was reported in Chapter 2, this paradigm suggests that physical properties of the global and local levels have perceptual equivalents. In addition, the processing of global information precedes the processing of the local information. Given the validity of this premise, the basic assumption of the global precedence hypothesis is that both the global and local levels are equally recognisable and none of them can be predicted from the identity of the other (Kimchi, 1992). Therefore, the difference in the processing of the global and local levels is assumed to originate from the interaction of the percepts of the global and local levels on each other. For example, Hughes, Layton, Baird, and Lester (1984) suggested that in the choice reaction time paradigm, the isolated local and global levels are equally discriminable. Therefore based on these worker's findings it is reasonable to conclude that differential reaction times to the local and global levels has its origin in being a part of a hierarchical structure.

The relationship between physical and perceptual properties of the global and local levels has been explained differently. In some studies (e.g., Kinchla & Wolfe, 1979; Lamb & Robertson, 1989; Navon, 1977), a linear correspondence between stimulus and perceptual structures has been suggested. In fact, according to this view a perceptual object is a psychological representation of the physical stimuli. This simplistic approach does not fit very well with the experimental results (Kimchi & Goldsmith, 1992). Referring to the literature was reviewed in Chapter 1 of this thesis, it seems that there are at least three domains in the perception of an object: the physical domain which describes the properties of stimuli reaching the receptors, the conscious domain which concentrates on the subjective experience of the perceived stimulus, and the functional domain which studies the nature of perceptual codes used for perceptual processing (Treisman, 1986). Previous research has produced contradictory results on the nature of these domains, and the extent to which these domains co-vary. This controversy partly derives from lack of understanding of the perceptual organisation regarding to the perception of the global and local levels.

Referring to what mentioned in chapter 1 dimensions, features, and parts are perceived differently. Also the perception of integral and separable dimensions is different. In addition, perception of parts is affected by their number and size. It has been suggested (e.g., Pomerantz, 1983) that processing of integral dimensions is associated with wholistic processing, whereas the analytic mode of processing involves perceiving separable dimensions. From an extensive review of literature and the study of classifications provided by Pomerantz (1981), Lasaga (1989), and Kimchi (1983), I suggested a classification of global-local relationship in Chapter 1 which seems to fit better with the global precedence hypothesis.

The review of the empirical findings and conceptual explanations concerning whole and parts, and global and local which were mentioned in Chapters 1 and 2, leads to the conclusion that previous research has produced contradictory results and ambiguities. The explanation provided on the difference between the concepts of whole and global does not seem to be a strong argument. Meanwhile, controversy in the data, and lack of preciseness and agreement among the classifications of the compound stimulus (e.g., Garner, 1974; Kimchi, 1983, 1992; Lasaga, 1989; Pomerantz, 1983), suggest the need for a better understanding of the global-local relationship.

The concepts of global and local, and the attributed relationship between these two varies among different studies. Referring to my classification of global-local relationship in Chapter 1, in the crudest sense global and local may refer to the outer and inner features of a visual object which have inclusion relationships with each other. That means the most distinct aspect of the global and local relationship is that contours of the global feature surround the local shape. In this type of the relationship the local level does not constitute the global configuration in a sense that a special arrangement of some small letters forms a large letter. For example, a map of France is a figure located within the map of the Europe. Although it is a part of the Europe, to identify Europe it does not seem to be necessary to identify France or the other European countries or vice versa, although the recognition of any of them may facilitate the recognition of the other. On the other hand, it seems that in normal vision external contours of the global level and the

recognition of one or two local components are enough for the recognition of the global pattern. It is at the outer contours of the objects that major discontinuities in the optical flow occur when either the viewer or the object move (Earhard, 1990). Therefore, this type of global/local relationship -inclusion- seems to be very common in normal vision.

In the previous chapters the global/local advantage and global/local interference hypotheses were studied using stimuli with placeholder relationship. In the present chapter the global advantage and global/local interference will be examined using stimuli with inclusion relationship. Evidence with regard to this type of global-local relationship is for the most part, indirect. The only studies which are related to this area are the studies conducted by Earhard and Walker (1985) and Earhard (1990) on outside-in processing. Because of the importance of these two studies a detailed explanation of them will be provided below.

Outside-in Processing

Earhard and Walker (1985) conducted five experiments to examine the discriminability of line elements as a function of inner and outer locations. Line drawings of forms such as octagons, crosses, and sets of small and large forms of rectangles and diamonds were used as the stimuli (Figure 28). The task was to detect the location of a line within a given form. The target line was thinner than the other lines of the form and it was either as an inner or outer line. Therefore, the subjects were required to divide their attention between the two levels. In experiment 1 they used stimuli with a visual angle of 0.81° horizontally and 1.38° vertically. Experiment 1 was designed to test outer-line advantage with larger forms. The visual angle of the largest outer form in their second experiment was 3.24° . The results of these two experiments indicated an outer-line advantage based on the accuracy levels. The small and large forms in Experiment 2 were presented in separate blocks. Meanwhile, in these two experiments inner-lines constituted smaller structural units than outer-lines. Therefore, there was the possibility that the difference in accuracy levels of discrimination of the inner and outer units was produced by the difference in the relative sizes of the two structures. There was also a possibility

that processing of inner lines was interfered with more than outer lines by the presence of the other lines. Earhard and Walker (1985) tested these two possibilities in their Experiment 3. In this experiment the sizes of the outside and inside lines were equated and they were presented in 'selective attention' conditions. The result of this experiment indicated no outer-line advantage when target lines were displayed in outside and inside

Figure 28. The set of stimuli used in Earhard and Walker (1985) and Earhard's (1990) studies.

figures within separate blocks in a 'selective attention' condition. Earhard and Walker interpreted the results of this experiment as an indication of the involvement of attention as the generator of the outer-line advantage effect. In Experiment 4, again, outer-line advantage was studied under selective and 'divided attention' conditions. The results of this experiment indicated a higher response accuracy level for the outside lines only in the 'divided attention' condition, and nonsignificant differences in the accuracies to the outer- and inner-lines in the 'selective attention' condition. Because of this result Earhard and

Walker suggested that the employed attentional strategy is the major determinant of outer-line advantage.

In all the above experiments the fixation point was in the centre of the stimulus. Experiment 5 (Earhard & Walker, 1985) was designed to study the outer-line effect when the fixation point was somewhere in a spatial location outside the stimulus form. Earhard and Walker proposed that if the effect disappeared when the fixation point was changed to a location outside the stimulus pattern, outline advantage might be attributed to a retinally tied, peripheral-to-central scanning process. The results of this experiment, again, were in support of an out-line advantage. That is outer-line targets were discriminated more accurately than inner-lines when the fixation point was in a location outside the stimulus form. Overall the results of these experiments indicated that outer lines were discriminated more accurately than inner lines. Meanwhile, from the presence of outline advantage in a 'divided attention' and not in a 'selective attention' condition, Earhard and Walker concluded that more accurate discrimination of outer details of a visual object is organised by an attentional strategy and is not a process originated from a retinally tied, peripheral-to central scanning.

In another series of five experiments, Earhard (1990) examined the discriminability of inner- and outer- line details under different experimental conditions. Line drawings of cross, octagon, and triangular forms were used as stimuli. The visual angle of the crosses and octagons varied in three conditions, 1.2°, 4.6°, and 9.1°. Triangular forms subtended visual angles of 1.2°, 3.7°, and 7.4° vertically and 1.4°, 4.3°, and 8.5° horizontally. In each form either the inner or outer line was drawn thinner than the other lines. The task was identification of the target line either at the outside or inside level. Accuracy level was recorded. In Experiment 2 only stimuli with large visual angles were used in divided-attention and selective-attention conditions. In the 'selective attention' condition targets occupying inner and outer location were presented in separate blocks. That is, in each trial subjects were required to attend either to the outside or inside level, in each trial, whereas in the 'divided attention' condition subjects were required to attend to the inner- and outer-target locations at the same time. Accuracy levels were recorded

for all the experimental conditions. Experiment 3 was the same as Experiment 2, but this time only the small version of stimuli was used, and reaction times to the identification of the target line at the inner and outer locations were recorded. The visual angle size of the small version of the stimulus configurations was less than 1.4° . Experiment 4 was conducted under size and location uncertainty conditions and accuracy levels were recorded. Experiment 5 tested outer-line advantage when the subject fixated in the middle of the screen while stimuli were presented simultaneously in the top, bottom, right, or left positions. Similar to the other experiments the task was the identification of the location of the target figure either at the outside or the inside level. Again, response accuracies were recorded for outer and inner target line at any of the four locations.

The main objective of this series of experiments was to examine the generality of the outer-line advantage effect and to study the role of attentional factors on this effect. The results indicated that the outer-line was discriminated more accurately than the inner-line under a wide variety of experimental conditions. Although the reaction time to the outer line was faster than those to the inner line when the visual angle of the stimulus configuration was less than 1.4° , response times to the outer lines and inner lines were not measured for stimuli with stimuli with larger visual angles.

According to Earhard there may be two nonattentional approaches to the outer-line advantage. One approach assumes that outer lines are more salient than the inner lines because they are not inhibited by the adjacent element in comparison to inner-lines which have been inhibited by their adjacent lines. In fact, it may be argued that inner lines are more inhibited than outer lines because they are surrounded by lines on all sides, whereas outer lines are free from adjacent lines on at least one side. Earhard (1990) suggested that the results of his second experiment did not confirm the role of lateral inhibition in the outer-line advantage paradigm. In fact, if lateral inhibition was the source of the outer-line advantage, it must be present in both selective and 'divided attention' conditions. This was not observed. Meanwhile, Earhard proposed that it was difficult to reconcile the outer-line advantage with a temporal precedence interpretation. If outer-line advantage was due to earlier availability of outside components, this effect would be repeated both

in selective and 'divided attention' conditions. Earhard (1990) suggested that the outer-line advantage reflected an attentionally driven, top-down process. Earhard proposed two reasons for attentional priority. One is that the outer contours are the major discontinuities in the optical flow pattern when the object or viewer moves. Therefore, outer-line preference may be as a result of people's life long experience of real life viewing situation. This practice may be entrenched early in life and may become automated by experience. The second interpretation of Earhard for outer-line advantage is that specifying the outer boundaries of objects provides the extent of an eye movement and attentional shift onto the potentially interesting locations.

The Present Study

Evidence concerning global-local relationship of the inclusion type is, for the most part, in direct. The outside-in hypothesis, especially the experiment conducted by Earhard and Walker (1985, Experiment 2) with rectangles and diamonds as stimuli, indicates similarities with the definition provided in Chapter 1 of compound patterns of inclusion relationship. Speed of processing to the outside and inside levels was examined in only one of Earhard's (1990) experiments. In that experiment an outer-line advantage was found for stimuli with visual angles of less than 1.4° . Review of empirical findings (See, Kinchla & Wolfe, 1979; Lamb & Robertson, 1989) suggested a possible effect of visual angle size of the stimulus on the global/local advantage effect. Meanwhile, the previous findings of the present study suggested quadratic functions for the pattern of responses to the global and local levels. The findings of Chapter 3 indicate that pattern of responses to not only global and local levels, but also to a single presentation of a stimulus of the same size as the global or local levels, formed a quadratic function. This quadratic function suggested the possibility that if the size and eccentricity of the global and local levels proportionally increase there may be a condition in which speed of processing of the local level precedes the speed of processing of the global level. As was mentioned, there is no study on the effect of variation in the reaction times to the identification of including (outside) and included (inside) figures in the global precedence paradigm of inclusion

relationship. Given the validity of the findings of the previous chapters, it seems that if size of including (outside) and included (inside) figures proportionally enlarge, there may be a size/eccentricity visual angle in which the reaction time to the included figure is faster than the including one. That means there will be a point in which the order of processing will change in favour of the included (inside) level.

6.1 Experiment 8

Earhard (1990) and Earhard and Walker (1985) provided evidence that outer-lines in comparison to inner-lines were more correctly identified in a 'divided attention' (randomised experimental presentation) condition, but there was no significant difference between the two levels in a selected attention condition. From these findings they concluded that higher accuracy rate to the global level reflected the deployment of an attentional strategy to process outside lines prior to the inside ones. Although they studied response latencies to the outer- and inner-lines in a condition in which the visual angle size was less than 1.4° (Earhard, 1990, Experiment 3), they did not examine the effect of variations in visual angle size on the reaction times to the processing of outer- and inner-lines. In Experiment 8, the effect of variations in size/eccentricity was examined on the processing of including (outside) and included (inside) figures. This effect has not been studied in the literature.

Method

Subjects

Twenty-one undergraduate students at the University of Wollongong served as subjects. All had normal or corrected to normal vision. They received course credit in return for their participation. Each subject participated in one experimental session, approximately 20 to 25 minutes of duration.

Apparatus and Stimuli

The stimuli were programmed and generated by an IBM AH compatible computer with a VGA monitor. The monitor had a matrix size of 640 x 480 pixels. Each pixel was associated with an image of 0.37 mm in length and 0.39 mm in width of the monitor. The stimuli were made of number of pixels per element. The experiment was conducted in a darkened room. All stimulus events were white on a black background, giving a very high contrast. The luminance of the test, mask, and fixation stimuli which was measured by TEKTRONIX J6526 1° Narrow angle luminance probe, was approximately 2 cd/m².

Figure 29. The set of stimuli used in Experiment 8.

Stimuli were two concentric circles only one of which, either the including or the included one, had an opening of 20° either to the right or to the left. There were two series of stimuli that differed in visual angle size the stimuli (Figure 29). In the small visual angle condition (type A) the diameters of the included (inside) and including (outside) circles measured 14 mm (1 deg) and 58 mm (4.15 deg), respectively. In the large visual angle (type B) condition the diameters of the included and including circles subtended 58 mm (4.15 deg) and 175 mm (12.34 deg), respectively. Thus, the including figure of small visual angle condition had the same size as the included figure of the large visual angle condition. Since the fixation stimulus and the centre of the circles coincided

with each other, the eccentricity of any of the circles was half of its visual angle size. Therefore, the eccentricities of the global and local stimuli were 6.17° and 2.075° for the large condition, and 2.085° and 0.50° for small condition. The subjects' task was to identify the direction of the opening of either the including or the included figure.

Design and Procedure

The stimulus was presented to the subjects for 50 msec. The task was to indicate whether the property of opening either at the including (outside) or included (inside) level was to the right or to the left. A circle with an opening to the right was to be responded to by pressing a specially marked key with the right index finger, and an opening to the left by pressing an other specially marked key with the left index finger. Viewing was binocular. The experiment was conducted individually in a single session. The subjects sat with their chin resting on a chin rest located 80 cm away from the screen of the monitor. Subjects were advised to respond to the direction of the opening of either the including or included circle. In each trial only one of the including or included figures had an opening either to the right or to the left. Therefore, to indicate the direction of the opening, subjects had to divide their attention between the two levels. Each experimental session consisted of a tutoring tour, two practice and four experimental blocks. The experimental session began with a programmed tour which was the explanation of the nature of experiment and the task, followed by two practice blocks. One of the practice blocks was targeted to the large visual angle condition and the other was allocated to the small visual angle condition. The order of these two blocks was randomised across the subjects. Four experimental blocks came after the practice trials. Two of the experimental blocks were allocated to the large visual angle condition and the other two to the small visual angle condition. The order of experimental blocks was counter balanced across the subjects. There were 20 trials in each practice block. Each experimental block consisted of forty trials which were arranged randomly from any of the four patterns of either type A or B condition (Figure 29).

A trial started with a 500 msec beep followed by 1 second presentation of a '+' sign in the middle of the screen as the fixation point. Then the test stimulus was presented accompanied by the same '+' sign in its centre, which was the centre of the display screen, too. That means the fixation stimulus stayed on the screen until the end of the display of the test stimulus. They were both replaced by a mask consisting of randomly located slashes and back slashes, exactly similar to the one used in Experiment 1. The mask disappeared after a correct response, or after a time-out of 2 seconds. Only wrong responses were followed by an auditory feedback. The next trial began with the appearance of the fixation stimulus 2000 msec after the previous response or the disappearance of the mask. The subjects were required to respond as fast as possible but to avoid errors. Reaction times and accuracies were recorded.

Results and Discussion

Mean reaction times (RTs) and accuracy rates to the including and included figures of the large and small stimulus series are presented in Table 32 (Appendix D) and Figure 30. The data entered the analysis and graphed were derived from means of the subject's means. The RT data were analysed by a three factor repeated measures analysis of variance (ANOVA). The factors were target level (including or included), visual angle condition (large, small), and the direction of the opening of the target level (right or left). The analysis indicated only a significant main effect of visual angle size, $F(1,20) = 16.66$, $p < 0.0006$. Although there was no significant main effect of target level, the significant interaction of target level and visual angle size, $F(1,20) = 45.21$, $p < 0.0001$, suggested that the reaction times to the including and included levels varied across visual angle conditions. Further analysis indicated that the including figures were identified faster than the included ones (Figure 30) when the visual angle of the stimulus was small $F(1,20) = 20.88$, $p < 0.0002$. However when the visual angle of the stimulus was large, the property of opening on the included figure was identified faster than when it was on the including shape, $F(1,20) = 24.18$, $p < 0.0001$. Both target levels were detected faster

when the direction of the opening was to the left than to the right, $F(1,20) = 32.16$, $p < 0.0001$.

The accuracy rates of any of the outside and inside levels in any of the large or small visual angle conditions were low (Table 32, Appendix D). That means error rates in any of these conditions were less than 3 percent. However, since the variation in accuracy rate was high, similar analysis was conducted on accuracy proportions. The factors and the levels of factors were the same as latency analysis. The results did not indicate any

Figure 30. Mean reaction times as a function of target level and visual angle in Experiment 8.

other significant main effect or interactions of in RT and accuracy analysis (Tables 36 & 37, Appendix D).

The main finding of the present experiment was the variation of the response latency to the including and included figures according to the visual angle of the stimuli. In the small visual angle condition the target property was identified quicker at the including level than the included one. However, in the large visual angle condition the target feature was

detected faster in the included (inside) than the including (outside) level. Since the including level of the small visual angle condition had the same size as the included level of the large visual angle condition, it may be concluded that there is an optimum size/eccentricity visual angle in which the speed of processing of a proportional enlargement of a stimulus is faster than the other size/eccentricities. This finding was compatible with the findings of Chapters 4 and 5 in which quadratic functions were found for the pattern of responses to the global and local levels. The data of the present experiment suggested that proportional enlargement of a compound shape of an inclusion-Type resulted in a change in the direction of the temporal order of processing of the including and included levels.

6.2 Experiment 9

Although in Experiment 8 attention was divided between the stimulus levels, it was channelled to the relevant level after stimulus onset due to response relevance. Since the irrelevant channel contained no response-associated stimulus, it seems that it could be very easily rejected. That means attending to one of the levels will be harder if both relevant and irrelevant channels contain stimuli that are associated with the response in a Stroop-type task (Navon & Norman, 1983). The amount of interference exerted by the irrelevant channel on the processing of information on the relevant channel may be used as the indicator of attentional priorities in the processing of the levels of a compound shape of inclusion-Type. The effect of interference of either the including (outside) or included (inside) level on reaction times to the other level, because of the consistency/inconsistency of the two levels, has not been studied in the literature. One of the purposes of Experiment 9 was to study this effect. The second objective of this experiment was to examine the effect of variations in the visual angle size on response latencies, in a blocked experimental presentation (selective attention) condition, where the stimulus consisted of response-associated including and included levels. Earhard (1990) and Earhard and Walker (1985) suggested that more accurate discrimination of outer details reflects an employment of an attentional strategy by the subject. Therefore, outer-

line accuracy advantage, according to these workers, does not occur in a blocked (selective attention) condition. The third objective of the present experiment was to test temporal order of processing of the including and included levels, in a blocked (selective attention) condition.

Method

Most of the details of the method of this experiment were similar to the corresponding ones in Experiment 8 except for the following: Twenty subjects from the same pool as the previous experiment participated in this experiment. None of them had

Figure 31. The set of stimuli used in Experiment 9.

participated in Experiment 8. Each experimental session consisted of one tutoring tour and four experimental blocks. Subjects were presented with stimuli showed in Figure 31. Similar to the previous experiment there were two visual angle conditions: large and small. Before each experimental block, subjects were advised whether they had to respond to the including (outside) or included (inside) figures. In the included condition subjects were required to respond to the inside figure and to ignore the outside one. In contrast, in the including condition they had to ignore the inside figure and to attend to the outside shape. The combination of the two visual angles and the two target level

conditions made four conditions. One experimental block was assigned to any of these four conditions. That means there were four experimental blocks all together. Each block consisted of 60 trials. The first 20 trials served as practice trials. Order of blocks was counterbalanced across subjects.

Results and Discussion

The RT and accuracy data for this experiment, by visual angle condition and target level, are displayed in Table 33 (Appendix D) and Figure 32. The RT data were analysed using a repeated measures analysis of variance with target level (including or included), consistency (consistent versus inconsistent), visual angle size (large versus small), and direction of the opening of the target level (right or left) as the factor. The analysis did not indicate a significant main effect of target level. The attended level was identified faster when it was consistent with the unattended level than the condition it was inconsistent with the unattended level. This was shown by the significant main effect of consistency, $F(1,19) = 56.00$, $p < 0.0001$. Meanwhile, a target level with an opening to the left was identified faster than a target level with an opening to the right, $F(1,19) = 19.47$, $p < 0.0001$. The significant interaction of target level and visual angle size, $F(1,19) = 93.02$, $p < 0.0001$, indicated that speed of processing of the including and included figures varied due to the visual angle of the stimulus. More detailed analysis revealed that in the small visual angle condition including (outside) figures were identified faster than the included (inside) ones in both consistent, $F(1,19) = 19.78$, $p < 0.0003$; and inconsistent, $F(1,19) = 56.67$, $p < 0.0001$; conditions. In contrast, in the large visual angle condition the included figures were recognised faster than the including ones in both consistent, $F(1,19) = 16.70$, $p < 0.0006$; and inconsistent, $F(1,19) = 38.99$, $p < 0.0001$; conditions (Figure 32). This was also reflected in the significant interaction of target level, visual angle size, and consistency, $F(1,19) = 8.01$, $p < 0.0057$. Although a target level with an opening to the left was recognised faster than a target level with an opening to the right, there were variations in the magnitude of this main effect according to the target level and visual angle size. These were reflected in the significant interaction

of target level and direction of opening, $F(1,19) = 6.96$, $p < 0.0097$; the significant interaction of visual angle and direction of opening, $F(1,19) = 10.02$, $p < 0.0021$; and the significant interaction of target level, visual angle size, and direction of opening, $F(1,19) = 6.46$, $p < 0.0126$.

The main finding of the present experiment was that the order of the processing of the including and included figures varied according to the visual angle of size/eccentricity of the stimulus. Therefore, the pattern of RTs which was found in Experiment 8 did not change in a blocked (selective attention) condition. That is there was a reversal in the

Figure 32. Mean RTs as a function of target level, visual angle, and consistency in Experiment 9.

order of processing of the including and included levels according to the visual angle of the stimulus in both blocked and randomised (selective and divided attention) conditions. Meanwhile, in contrast to the findings of Earhard (1990) and Earhard and Walker (1985) on accuracy data, the latency analysis indicated that pattern of responses did not change by attentional conditions, 'selective versus 'divided attention' strategies.

Because of the variations in accuracy proportions and their considerably high standard deviations (Table 33, Appendix D) similar analysis was conducted on accuracy proportions. The factors and their levels were the same as latency analysis. The results of a four-way repeated measures ANOVA revealed only a significant main effect of consistency, $F(1,19) = 20.92$, $p < 0.0001$. A target level which was consistent with the unattended level was identified more accurately than the target level which was inconsistent with the unattended level. Although there was not any significant difference between the accuracy proportions to including and included levels of the stimulus of large visual angle, including (outside) level of small visual angle stimulus was identified faster than the included level. This was reflected in the significant interaction of the accuracy proportions to the target level and visual angle size, $F(1,19) = 5.41$, $p < 0.0211$. The accuracy and RT data were consistent with each other in small visual angle condition where error proportions exceeded significance level (0.05) in some conditions. Therefore, none of the results of latency analysis in this condition could be attributed to a speed-accuracy trade-off. On the other hand in the large visual angle condition where RT and accuracy data were not consistent with each other, the error rates were below the significant level (0.05). There was no other significant main effect in accuracy and RT analysis (Tables 36 & 37, Appendix D).

If the interference is measured by the difference in reaction times to the any of the levels in consistent and inconsistent condition, the amount of interference in the small visual angle is 8 msec ($343 - 335 = 8$) for the including figures and 24 msec for included figures. That means in the small visual angle condition the amount of interference of the identity of the unattended including (outside) figures on the attended included (inside) figures was stronger ($21 - 8 = 13$ msec) than vice versa. However, in the large visual angle condition the magnitude of interferences was 18 msec at the including and 14 at the included level and the magnitude of interference was slightly (4 msec) in favour of the included figure. Therefore, the effect of visual angle size on processing of the including and included figures was reflected not only in the pattern of RTs, but also in asymmetric interference of the two levels on each other.

General Discussion

In Experiment 8, the response latency to compound stimuli of the inclusion-type were studied in small and large visual angle conditions and in a blocked experimental presentation (selective attention) condition. The results demonstrated an including (outside) advantage in the small visual angle condition and an included (inside) advantage in the large visual angle condition. These findings were replicated in Experiment 9. There was a Stroop-type semantic relationship between the levels of the stimulus in the latter experiment. Meanwhile, Experiment 9 was conducted in a blocked (selective attention) condition. The results of this experiment indicated that the instruction to attend selectively does not guarantee 'selective attention,' therefore as suggested previously using the term blocked versus randomised experimental presentation condition seems to be more appropriate than the former concept. The data indicated that the presence of response associated stimuli in an unattended channel interfered with the processing of the relevant channel. In the small visual angle condition, the interference of the unattended including (outside) figure on the attended included (inside) patterns was stronger than vice versa. However, in large visual angle condition the interference of the unattended included figure on the attended including figure was stronger than vice versa. Since in both randomised and blocked experimental presentation conditions and with response-associated and response-irrelevant stimulus, stimuli of medium size were processed faster than the small or large stimuli, it may be concluded that speed of processing of the including and included levels was not determined by the experimental presentation conditions (randomised versus blocked) or the stimulus-type. The fact that the size of the including figure of the small visual angle condition was the same as the size of the included level of the large visual angle condition, and reaction times to this size of stimuli in both experiments were faster than the smallest included or the largest including figures, provides a strong support for the interpretation of the pattern of responses to the structural levels of a compound shape with an inclusion relationship, according to the size and eccentricity of the stimulus.

Perceptual properties of compound shapes have been the subject of many studies (e.g., Garner, 1974; Kimchi, 1983, 1992; Kimchi & Goldsmith, 1992; Lasaga, 1989; Pomerantz, 1981, 1983). Different explanations have been provided for the relationship between physical and perceptual objects within the context of the global precedence paradigm. To date, there has been no comprehensive explanation of this relationship. In the present study four types of global and local relationships were introduced: inclusion, placeholder, dimensional, and featural. These categories are based on the structural-functional relationship between the two levels. Apart from these structural relationships the global and local levels may or not be semantically related. In the previous chapters processing of the global and local levels of hierarchical structures of the placeholder-type was studied. In the present chapter another type of global-local relationship, inclusion, was examined.

Evidence concerning inclusion relationships is for the most part indirect. As was mentioned, the closest study of this type was conducted in the outside-in paradigm. It seems that the concepts of including and included figure fits better with the inclusion relationship than with the outside and inside relationship. In the present study, the effect of the visual angle of size/eccentricity on the speed of processing of the including and included figures of a compound stimulus with an inclusion relationship was studied. The findings of the experiments of Chapter 4 and 5 combined with the results of the present chapter reveal that reaction times to the proportional enlargement of either global or local levels of the stimulus with inclusion and placeholder relationship, either with or without semantic relationship, decrease in the middle of visual field. This pattern does not seem to be determined by the relationship between the global and local levels (i.e., inclusion or placeholder), experimental presentation conditions (blocked or randomised), stimulus type, or semantic relationship of the stimulus levels. Those results, along with the present data, suggest that the relative speed of processing of the structural levels of the inclusion and placeholder relationships is determined by the size and eccentricity of the levels. Based on the data of the previous chapters and the findings of the present experiments it seems that assuming all the other variables are constant, an increase in the size of any of

the including or included levels will provide an increase in speed of processing of that level if the eccentricity is constant. On the other hand, an increase in eccentricity generally may result in an increase in reaction times. Meanwhile, it appears that temporal order of processing of the structural levels of these types of stimuli and the amount of interference of the identities of the two levels on each other, are determined by separate mechanisms. A complete understanding of these two mechanisms should await further research and conceptual clarifications on the compound stimuli of the dimensional- and featural-types.

Chapter 7

Summary and Conclusions

Whether the earliest perceptual stages reflect our subjective experience of wholistic objects which are later analysed into distinct properties, or whether initial properties and events synthesise to form a state of awareness, is an enduring issue both in epistemology and psychology. Global/local precedence hypothesis is a modern version of this old debate. This hypothesis provides an experimental framework to investigate the nature, origin, and methods of human knowledge; and the circumstances of how perceptual organisation integrates temporally and spatially segregated percepts.

Three levels or domains can be differentiated in the perception of a stimulus: the physical domain which describes the properties of stimuli reaching the receptors, the conscious domain which concentrates on the subjective experience of the perceived stimulus, and the functional domain which is related to the nature of perceptual codes used for perceptual processing. The study of the latter domain, forms what is called perceptual organisation. Our subjective perception of the global and local levels of physical properties of a compound pattern does not necessarily correspond with the perception of these properties at the functional levels (Kimchi, 1992).

It seems that part of the controversy in the global precedence paradigm originates from the fact that global and local levels of all compound pattern do not bear the same relationship with each other at the functional level of the visual perception. The present study suggested a new classification of global-local relationships. According to this approach the global-local relationship was classified into four groups: Inclusive, placeholder, dimensional, and featural relationships. It was suggested that any of these relationships may or may not be accompanied by a semantic relationship between the global and local levels. Based on an extensive study of the literature it was suggested that the perception of the global and local levels of a compound pattern is dependent on the type of the relationship between the two levels. Therefore, the perception of the global

configuration and local components may be influenced by the type of relationship between these two levels. The presented study was limited to test the effect of size and eccentricity on the processing of the global and local levels of compound patterns with inclusion and placeholder relationship.

The rationale behind a large number of studies in the global precedence hypothesis is that the global configuration and local components of a hierarchical pattern are equally complex, recognisable, and codable (Kimchi, 1992). In the present research this rationale was questioned by manipulation of the size and eccentricity of the global and local levels of compound patterns of inclusion and placeholder types. In Experiment 1 the effect of manipulation of the relative size of the global and local levels was studied when the stimulus was displayed in a peripheral location. The results indicated that reaction time to the local level decreased as the result of an increase in the size of local components, whereas the reaction time to the global level was insensitive to variations in the size of the local level. This finding suggested that reaction times to the global and local levels were determined by the absolute size of the levels. The variation in the relative size did not have a continuous effect on the interference effect. The local figures of the smallest size did not show any interference on the perception of the global level. Thus, it seems that very small local components simply behaved as placeholders. The medium size local level generated the highest amount of interference on the perception of the global size. Therefore, the results suggested the possibility of the existence of an optimum relative size at which the local level produces the largest amount of interference on the global configuration.

The results of Experiment 1 showed a left visual field advantage for both global and local levels. This advantage was insensitive to variation in size of the local level and to consistency/inconsistency of the levels. However, the data suggested the possibility that the non-letter local figures are less distracted in the right hemisphere, and the non-letter global configurations are less distracted in the left hemisphere. Meanwhile it was suggested that the interference of the levels and the speed of processing of the global and local levels were related to separate hemispheric mechanisms. Faster reaction times to both global and local levels displayed in the left visual field in comparison to the right

visual field in Experiment 1, is in contrast to the hemispheric specialisation hypothesis regarding the processing of global and local levels. The results of this experiment showed that the hemispheres are not probably specialised according to the speed of processing of the global and local levels. These results seem to fit better with the verbal/visuospatial dichotomy of hemispheric specialisation than whole/part dichotomy. Generally, inconsistency in the results concerning visual field advantage and global/local processing in Experiment 1 and other experiments reported in this thesis, and the existing controversy in the literature suggests that the generalisation of an association between global/local processing and hemispheric asymmetry for the most part is premature.

The series of experiments in Chapter 4 investigated more directly the global advantage and interference effects under different experimental conditions with stimuli whose global and local levels had placeholder relationships. Meanwhile the effects of size and eccentricity in the processing of the global and local levels were studied in that chapter. Experiments 2A, 3A, and 4A indicated that the global level was identified faster than the local level regardless of experimental presentation conditions, i.e., randomised versus block and size/eccentricity certainty versus uncertainty conditions. The similarity of patterns of responses in series A and series B experiments suggested that the quadratic patterns of responses to the global and local levels were not formed because of the employment of a specific attentional strategy or compoundness of patterns. The comparison of results of experiment series A and B suggested that the so called global advantage effect and the quadratic patterns of responses to global and local levels are formed by the joint effects of size and eccentricity. These findings showed that by the proportional enlargement of the stimulus the speed of processing reaches a minimum level as the stimulus is projected to somewhere between eccentricity 1.2° to 3.6° degrees.

Experiments 5 and 6 were designed to explore the nature of this quadratic function, and effects of size and eccentricity separately. Experiment 5 showed that when size was controlled and eccentricity varied, the reaction time increased with an increase in eccentricity, except for the most foveal locations. The results of this experiment indicated that when the eccentricity of a stimulus of a constant size increased from the most foveal

towards the most peripheral locations, there was an initial decrease, around eccentricity 1° , and then an increase in reaction times. Faster reaction time at eccentricity 1° suggested that the density of transient channels around this location is probably more than the other locations of the visual field.

In Experiment 6 eccentricity was controlled while size was manipulated. Results demonstrated that when the eccentricity was constant and size was manipulated, reaction times formed a decreasing exponential function. Small changes in the size of small stimuli created large changes in reaction times, whereas large changes in the size of large stimulus create relatively little changes on reaction times.

Together, the results of Experiments 5 and 6 explain the nature of the quadratic function of patterns of responses to series A and B experiments in Chapter 4. When size was controlled and eccentricity was manipulated, the reaction time formed an increasing linear function. The manipulation of size when eccentricity was controlled exhibited a decreasing exponential function. Adding these two functions together will result in a quadratic function which is associated with a condition in which both size and eccentricity are manipulated. The group of experiments in Chapter 4 is the first study of this kind which was designed to investigate the effects of size and eccentricity and their interaction within the framework of the global precedence hypothesis.

These results provide a possible explanation for the difference between studies which reported a turning point in the direction of global/local advantage according to the visual angle of the global configuration (e.g., Kinchla and Wolfe, 1979; Lamb and Robertson, 1990) and the studies based on the unidirectionality of the global/local advantage effect (e.g., Navon, 1977; Navon and Norman, 1983; Pomerantz, 1983). It seems reasonable to assume that when the local elements are fairly large and are mainly projected to a location around the eccentricity 1° , where the reaction time for their detection is at the minimum level, and the global configuration is displayed at the focal-most or peripheral-most locations, reaction time to the local level may become faster than the reaction time to the global level. In the present study there was not such a point in

which the minimum speed of processing of the local level preceded the maximum speed of processing of the global levels.

This series of experiments provided strong support for the temporal precedence of global information within the conditions I tested. Generally the response times to the global and local levels were determined by the relative size and eccentricity of the global configuration and local elements. However faster response time to the global configurations in comparison to the local elements, does not necessarily confirm the precedence of the wholistic in contrast to the analytic processing at the functional level. The group of experiments in Chapter 4 showed some slight variations in the speed of processing according to the task demand, however, the general trend of the identification of global configuration faster than small components, and the general pattern of the U-shaped RT functioning according to the proportional enlargement of the compound pattern did not change.

The idea underlying the so called global precedence hypothesis is that RT advantage of the global level together with global interference reflects the order of processing. However, as Lamb and Robertson (1989) argued, if RT advantage and interference reflect processing order they should covary in a systematic way. That means, global precedence is associated with the global advantage and interference and local precedence is associated with local advantage and interference. However, the results of Experiment 7 showed dissociation in RT advantage and interference data. Therefore, it may be suggested that the global/local interference and global/local advantage are regulated by independent mechanisms.

Using stimuli with either inconsistent or consistent levels, it was found that in size/eccentricity uncertainty conditions, the global level was identified faster than the local level across all size/eccentricity conditions. The use of response-associated stimuli, in Experiment 7, did not change the pattern of responses suggested by the findings of the previous chapter. This provided evidence that the findings with neutral stimuli may be generalisable to the consistent/inconsistent stimuli.

To the best knowledge of the writer of this thesis the present study is the only study which investigated interference effect in a wide range of eccentricities, and in size/eccentricity uncertainty condition when the confound of eccentricity was controlled. The results demonstrated that the variation in size/eccentricity did not produce a distinct pattern of responses according to the consistency at the global level. On the other hand, small local elements displayed at small eccentricities were facilitated by the consistent identity of the unattended global level, but large local elements displayed at the large eccentricities were interfered by the unattended consistent global configuration. Perhaps, the most important finding of Experiment 7 was that there was a discontinuity in the interference effect across eccentricity. Variations in the direction of the interference and its magnitude across the target level and eccentricity suggested that factors other than size and eccentricity may be involved in forming the pattern of results. Experiment 7 which is probably the first study, examining the consistency effect across a wide range of size/eccentricity conditions, exhibited that the global advantage and interference effects, are independent.

Chapter 6 studied global/local processing of stimuli with inclusion relationships. It seems that there is not any other study in the global precedence hypothesis with stimuli of this type of relationship. In Experiments 8 and 9 the effect of size and eccentricity on the processing of structural levels of compound patterns of inclusion relationship was studied. The results of Experiment 8 demonstrated an including (outside) advantage in the small visual angle condition and an included (inside) advantage in the large visual angle condition. In experiment 9 the same results were obtained when there was also a Stroop-type relationship between the two levels. Meanwhile, the results of this experiment indicated that the instruction to attend selectively does not guarantee selective attention. That is the presence of a response associated stimulus in an unattended channel may interfere with the processing of the relevant channel. However, the direction of interference was different in small and large visual angle condition.

The importance of the role of size and eccentricity in the speed of processing of the global and local levels of compound patterns of placeholder and inclusion types did not

buy any credit for either stationary or queue hypothesis discussed in Chapter 2. The results indicated that speed of processing of the global and local levels is mainly determined by size and eccentricity of the global and local levels. Also the results of Experiment 7 and variations in interference effect across the variables of size and eccentricity indicate that based on the available data it is not possible to decide whether the stationary or queue hypothesis is applicable with regard to global/local interference. Despite this, low level perceptual mechanisms clearly are important.

Qualifications and Limitations of the Present Thesis and Suggestions for Future Research: In this thesis I attempted to clarify several issues concerning the global precedence hypothesis, identify types of global-local relationships, and suggest possible locus and source of the global-local advantage and interference. The results of experiments reported in this research indicated that reaction times to the proportional enlargement of the global and local levels of the stimulus with either inclusion or placeholder relationship decrease in the middle of visual field. This pattern does not seem to be determined by the global-local relationship (placeholder versus inclusion), and attentional strategies ('selective or divided'). Meanwhile it was shown that size and eccentricity are the prime determinants of the global/local processing. The nonsignificant roles of divided versus selective attention and size/eccentricity certainty versus uncertainty conditions, and the determinant role of physical properties of the stimulus provided evidence concerning the relative importance of low-level mechanisms in the global precedence effect. However, these results do not rule out the role of post-perceptual factors which can be involved in the processing of compound patterns.

As was mentioned previously, the present study was limited to the investigation of global/local advantage and interference effects using compound patterns with placeholder and inclusion relationships. It might be speculated that the latter types of compound patterns are more sensitive to post-perceptual factors than the types of compound patterns used in this thesis. Therefore, the results are not probably generalisable to stimuli with featural and dimensional types. Another limitation of the series of experiments conducted

in this thesis is again with regard to the stimulus-type. Stimuli used in Experiments of Chapters 3 and 6 were geometric patterns. In Experiments of Chapters 4 and 5, the stimuli were defined as Cs facing the right or the left, but there is the possibility that subjects employed a strategy to identify these patterns as circles or arches with an opening to the right or to the left. Although the global precedence hypothesis by definition is not restricted to letter-type stimuli, the findings of the present experiment would be more generalisable if they were replicated with this type of stimuli. Meanwhile, in this I chose global/local advantage and Stroop-type interference as the performance measures of the theoretical concept of the 'global/local precedence'. The study of the variables under investigation with other performance measures such as Garner interference, and using other task demands such as classification task will help better understanding of the results in hand.

Because of the distinct patterns of responses with regard to the effects of size and eccentricity in the present study I would suggest to all workers investigating 'global/local precedence hypothesis' to control the confound of eccentricity while manipulating the effect of size, to test the possible effects of size and eccentricity with the other types of compound patterns and tasks. Special concern should be given to the variations in global/local interference of Stroop-type across eccentricity. Based on the present results global advantage appears to be a more reliable measure of the so called 'global/local precedence effect' than the Stroop-type interference. Repetitive reversals in the effect of consistency across eccentricity obtained in Experiment 7 makes the generalisability of global/local Stroop-type interference doubtful.

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APPENDICES

Appendix A

(Tables of Chapter 3)

Table 1. Effect of Consistency on Reaction Times According to the Relative Size of the Global and Local Levels in Experiment 1.

	Consistent Global and Local		Inconsistent Global and Local	
Relative Size	Global (RTs)	Local (RTs)	Global (RTs)	Local (RTs)
Type A	511 (SD = 98)	575 (SD = 109)	511 (SD = 90)	598 (SD = 101)
Type B	503 (SD = 91)	555 (SD = 89)	516 (SD = 95)	574 (SD = 87)
Type C	508 (SD = 98)	542 (SD = 82)	512 (SD = 94)	571 (SD = 95)
All	507 (SD = 96)	557 (SD = 95)	513 (SD = 93)	581 (SD = 96)

Table 2. Effect of Consistency on Accuracy Rates According to the Relative Size of the Global and Local Levels in Experiment 1.

	Consistent Global and Local		Inconsistent Global and Local	
Relative Size	Global (%)	Local (%)	Global (%)	Local (%)
Type A	0.99 (SD = 0.08)	0.99 (SD = 0.09)	1.00 (SD = 0.07)	0.99 (SD = 0.09)
Type B	1.00 (SD = 0.06)	1.00 (SD = 0.05)	0.99 (SD = 0.11)	0.99 (SD = 0.10)
Type C	1.00 (SD = 0.00)	1.00 (SD = 0.04)	0.99 (SD = 0.11)	0.99 (SD = 0.09)
All	1.00 (SD = 0.06)	1.00 (SD = 0.06)	0.99 (SD = 0.10)	0.99 (SD = 0.09)

Table 3. Analysis of Variance on RTs in Experiment 1.

Source	D.F.	M.S.	F	Pr
Main Effects and Interactions:				
T (Target Level)	1	4337636.0059	324.86	0.0001
Error (T)	28	13352.3578		
R (Relative Size)	2	86911.9434	10.95	0.0001
Error (R)	56	7939.1192		
C (Consistency)	1	264675.8838	35.13	0.0001
Error (C)	28	7534.7029		
V (Visual Field)	1	137833.3708	41.32	0.0001
Error (V)	28	3335.3976		
G (Identity of the Global Level)	1	86712.0562	13.88	0.0009
Error (G)	28	6249.3545		
L (Identity of the Local Level)	1	67168.9872	4.43	0.0444
Error (L)	28	15157.7521		
F (Fixation Stimulus)	1	1707.0562	0.16	0.6904
Error (F)	28	10537.5130		
T*R	2	115786.0587	16.71	0.0001
Error (T*R)	56	6927.3327		
T*C	1	38740.6553	4.39	0.0454
Error (T*C)	28	8833.1732		
R*C	2	11206.3051	2.23	0.1174
Error (R*C)	56	5033.0010		
T*V	1	23888.3062	1.89	0.1797
Error (T*V)	28	12614.6001		
R*V	2	2045.6262	0.40	0.6704
Error (R*V)	56	5078.3254		

Table 3 (cont.)

Source	D.F.	M.S.	F	Pr
C*V	1	4222.8450	0.47	0.4964
Error (C*V)	28	8892.9476		
T*G	1	135534.4542	19.95	0.0001
Error (T*G)	28	6794.4750		
R*G	2	41596.0378	7.64	0.0012
Error (R*G)	56	5445.0622		
C*G	1	1281.2932	0.10	0.7494
Error (C*G)	28	12308.2374		
V*G	1	13816.5303	1.13	0.2978
Error (V*G)	28	12275.8741		
T*L	1	4.8895	0.00	0.9802
Error (T*L)	28	7786.5197		
R*L	2	1623.4441	0.23	0.7982
Error (R*L)	56	7172.7419		
C*L	1	491.9225	0.06	0.8100
Error (C*L)	28	8347.5580		
V*L	1	4363.3335	0.88	0.3570
Error (V*L)	28	4974.2152		
G*L	1	1751.6395	0.34	0.5672
Error (G*L)	28	5224.3419		
T*F	1	26.6208	0.00	0.9572
Error (T*F)	28	9076.1335		
R*F	2	18283.3676	2.24	0.1162
Error (R*F)	56	8172.0995		
C*F	1	1141.4225	0.13	0.7174
Error (C*F)	28	8537.6949		

Table 3 (cont.)

Source	D.F.	M.S.	F	Pr
V*F	1	6764.1467	0.98	0.3304
Error (V*F)	28	6894.4034		
G*F	1	7.8450	0.00	0.9735
Error (G*F)	28	6979.7497		
L*F	1	50.6395	0.00	0.9487
Error (L*F)	28	12028.6760		
T*R*C	2	21547.5303	2.92	0.0622
Error (T*R*C)	56	7377.9717		
T*R*V	2	5157.5411	0.96	0.3905
Error (T*R*V)	56	5392.8869		
T*C*V	1	2669.0059	0.38	0.5400
Error (T*C*V)	28	6933.2581		
R*C*V	2	1104.6251	0.22	0.8038
Error (R*C*V)	56	5037.7060		
T*R*G	2	20914.1029	4.24	0.0192
Error (T*R*G)	56	4928.3765		
T*C*G	1	5100.2588	0.90	0.3507
Error (T*C*G)	28	5662.0400		
R*C*G	2	10517.9484	1.63	0.2047
Error (R*C*G)	56	6444.8106		
T*V*G	1	47852.0705	5.28	0.0293
Error (T*V*G)	28	9068.6234		
R*V*G	2	389.8514	0.06	0.9434
Error (R*V*G)	56	6688.1968		
C*V*G	1	4129.3148	0.45	0.5064
Error (C*V*G)	28	9115.3282		

Table 3 (cont.)

Source	D.F.	M.S.	F	Pr
T*R*L	2	67.4854	0.01	0.9906
Error (T*R*L)	56	7173.5994		
T*C*L	1	5931.7544	0.74	0.3962
Error (T*C*L)	28	7988.2477		
R*C*L	2	1166.2124	0.16	0.8494
Error (R*C*L)	56	7125.4254		
T*V*L	1	12.2343	0.00	0.9690
Error (T*V*L)	28	7936.7061		
R*V*L	2	252.6664	0.07	0.9365
Error (R*V*L)	56	3849.0375		
C*V*L	1	51313.1122	10.41	0.0032
Error (C*V*L)	28	4926.9924		
T*G*L	1	24707.1553	4.91	0.0350
Error (T*G*L)	28	5033.7602		
R*G*L	2	19032.0522	3.33	0.0430
Error (R*G*L)	56	5715.3020		
C*G*L	1	14550.6467	1.79	0.1912
Error (C*G*L)	28	8111.8967		
V*G*L	1	5115.5835	1.05	0.3133
Error (V*G*L)	28	4851.3283		
T*R*F	2	4892.5303	0.59	0.5577
Error (T*R*F)	56	8292.2332		
T*C*F	1	2814.9570	0.43	0.5172
Error (T*C*F)	28	6542.3075		
R*C*F	2	4322.5648	0.93	0.4021
Error (R*C*F)	56	4667.7149		

Table 3 (cont.)

Source	D.F.	M.S.	F	Pr
T*V*F	1	15250.7588	2.68	0.1126
Error (T*V*F)	28	5684.8644		
R*V*F	2	4027.6187	0.43	0.6554
Error (R*V*F)	56	9461.7788		
C*V*F	1	18887.3967	3.94	0.0571
Error (C*V*F)	28	4796.5165		
T*G*F	1	1014.7501	0.18	0.6782
Error (T*G*F)	28	5770.1765		
R*G*F	2	152.5174	0.02	0.9800
Error (R*G*F)	56	7541.2943		
C*G*F	1	358.5792	0.07	0.7995
Error (C*G*F)	28	5455.2146		
V*G*F	1	330.7200	0.04	0.8401
Error (V*G*F)	28	7972.1180		
T*L*F	1	24029.3622	3.40	0.0759
Error (T*L*F)	28	7074.2030		
R*L*F	2	3204.8604	0.59	0.5594
Error (R*L*F)	56	5459.7144		
C*L*F	1	3775.5432	0.77	0.3887
Error (C*L*F)	28	4925.5261		
V*L*F	1	18998.0648	3.69	0.0650
Error (V*L*F)	28	5149.6928		
G*L*F	1	3609.4269	0.52	0.4752
Error (G*L*F)	28	6890.4395		
T*R*C*V	2	4844.8970	0.74	0.4812
Error (T*R*C*V)	56	6537.1364		

Table 3 (cont.)

Source	D.F.	M.S.	F	Pr
T*R*C*G	2	19306.7469	3.55	0.0353
Error (T*R*C*G)	56	5435.6783		
T*R*V*G	2	8453.3410	1.12	0.3334
Error (T*R*V*G)	56	7546.3308		
T*C*V*G	1	95.4455	0.01	0.9127
Error (T*C*V*G)	28	7795.1635		
R*C*V*G	2	26137.7598	4.24	0.0193
Error (R*C*V*G)	56	6167.0249		
T*R*C*L	2	594.3622	0.08	0.9250
Error (T*R*C*L)	56	7613.1563		
T*R*V*L	2	20498.7645	3.09	0.0533
Error (T*R*V*L)	56	6630.9154		
T*C*V*L	1	2264.6553	0.36	0.5523
Error (T*C*V*L)	28	6258.5348		
R*C*V*L	2	1885.0863	0.32	0.7294
Error (R*C*V*L)	56	5941.5050		
T*R*G*L	2	9940.4225	1.44	0.2450
Error (T*R*G*L)	56	6890.4744		
T*C*G*L	1	19511.3019	2.52	0.1237
Error (T*C*G*L)	28	7746.6196		
R*C*G*L	2	5685.3967	1.05	0.3558
Error (R*C*G*L)	56	5400.2722		
T*V*G*L	1	696.2932	0.07	0.7864
Error (T*V*G*L)	28	9299.4748		
R*V*G*L	2	2259.8766	0.30	0.7455
Error (R*V*G*L)	56	7655.0538		

Table 3 (cont.)

Source	D.F.	M.S.	F	Pr
C*V*G*L	1	2285.1093	0.35	0.5594
Error (C*V*G*L)	28	6546.9910		
T*R*C*F	2	4929.6176	0.86	0.4303
Error (T*R*C*F)	56	5757.5244		
T*R*V*F	2	1292.7878	0.25	0.7768
Error (T*R*V*F)	56	5096.5581		
T*C*V*F	1	10321.7602	1.43	0.2413
Error (T*C*V*F)	28	7203.1263		
R*C*V*F	2	9558.9904	1.39	0.2572
Error (R*C*V*F)	56	6870.5048		
T*R*G*F	2	12454.1413	2.10	0.1317
Error (T*R*G*F)	56	5924.6831		
T*C*G*F	1	1865.6122	0.39	0.5359
Error (T*C*G*F)	28	4749.5772		
R*C*G*F	2	10424.3539	2.13	0.1284
Error (R*C*G*F)	56	4895.4709		
T*V*G*F	1	1425.1955	0.25	0.6186
Error (T*V*G*F)	28	5624.8429		
R*V*G*F	2	389.6521	0.09	0.9129
Error (R*V*G*F)	56	4271.4212		
C*V*G*F	1	2556.6682	0.35	0.5592
Error (C*V*G*F)	28	7319.1928		
T*R*L*F	2	2865.1575	0.36	0.6967
Error (T*R*L*F)	56	7877.8001		
T*C*L*F	1	32872.4570	7.98	0.0086
Error (T*C*L*F)	28	4118.3410		

Table 3 (cont.)

Source	D.F.	M.S.	F	Pr
R*C*L*F	2	10052.3450	1.59	0.2122
Error (R*C*L*F)	56	6307.0047		
T*V*L*F	1	259.9154	0.05	0.8282
Error (T*V*L*F)	28	5417.1646		
R*V*L*F	2	5565.0303	0.76	0.4707
Error (R*V*L*F)	56	7285.6064		
C*V*L*F	1	3915.1510	0.57	0.4572
Error (C*V*L*F)	28	6888.8921		
T*G*L*F	1	40825.4182	8.32	0.0075
Error (T*G*L*F)	28	4908.3974		
R*G*L*F	2	13037.6575	3.04	0.0560
Error (R*G*L*F)	56	4294.9486		
C*G*L*F	1	28726.0432	4.23	0.0491
Error (C*G*L*F)	28	6791.3074		
V*G*L*F	1	15751.2975	2.04	0.1648
Error (V*G*L*F)	28	7739.9880		
T*R*C*V*G	2	11014.6955	1.57	0.2164
Error (T*R*C*V*G)	56	7000.7299		
T*R*C*V*L	2	408.8503	0.07	0.9334
Error (T*R*C*V*L)	56	5920.9759		
T*R*C*G*L	2	12037.5680	1.43	0.2473
Error (T*R*C*G*L)	56	8402.4510		
T*R*V*G*L	2	3837.4085	0.63	0.5369
Error (T*R*V*G*L)	56	6101.5583		
T*C*V*G*L	1	375.0044	0.04	0.8347
Error (T*C*V*G*L)	28	8455.8690		

Table 3 (cont.)

Source	D.F.	M.S.	F	Pr
R*C*V*G*L	2	38992.6298	5.38	0.0073
Error (R*C*V*G*L)	56	7247.8837		
T*R*C*V*F	2	13887.9865	1.80	0.1753
Error (T*R*C*V*F)	56	7731.3297		
T*R*C*G*F	2	393.4484	0.06	0.9441
Error (T*R*C*G*F)	56	6826.8660		
T*R*V*G*F	2	1098.8184	0.18	0.8318
Error (T*R*V*G*F)	56	5948.3859		
T*C*V*G*F	1	2043.3062	0.32	0.5762
Error (T*C*V*G*F)	28	6387.8582		
R*C*V*G*F	2	29716.7652	5.12	0.0091
Error (R*C*V*G*F)	56	5807.7390		
T*R*C*L*F	2	875.5249	0.13	0.8825
Error (T*R*C*L*F)	56	6990.7665		
T*R*V*L*F	2	10143.6858	2.09	0.1338
Error (T*R*V*L*F)	56	4864.3162		
T*C*V*L*F	1	2817.8019	0.63	0.4323
Error (T*C*V*L*F)	28	4438.0764		
R*C*V*L*F	2	19314.5659	2.62	0.0815
Error (R*C*V*L*F)	56	7364.4403		
T*R*G*L*F	2	1713.6887	0.28	0.7575
Error (T*R*G*L*F)	56	6139.6472		
T*C*G*L*F	1	2766.8148	0.33	0.5690
Error (T*C*G*L*F)	28	8331.6779		
R*C*G*L*F	2	3232.8633	0.42	0.6610
Error (R*C*G*L*F)	56	7751.3523		

Table 3 (cont.)

Source	D.F.	M.S.	F	Pr
T*V*G*L*F	1	1369.0950	0.47	0.4975
Error (T*V*G*L*F)	28	2897.3368		
R*V*G*L*F	2	1106.6305	0.18	0.8331
Error (R*V*G*L*F)	56	6040.7166		
C*V*G*L*F	1	102.3751	0.03	0.8542
Error (C*V*G*L*F)	28	2977.3677		
T*R*C*V*G*L	2	3845.2156	0.74	0.4824
Error (T*R*C*V*G*L)	56	5206.7917		
T*R*C*V*G*F	2	1614.7986	0.28	0.7547
Error (T*R*C*V*G*F)	56	5709.5276		
T*R*C*V*L*F	2	574.5756	0.11	0.8982
Error (T*R*C*V*L*F)	56	5341.6710		
T*R*C*G*L*F	2	1693.2889	0.39	0.6764
Error (T*R*C*G*L*F)	56	4300.5599		
T*R*V*G*L*F	2	15784.0475	2.65	0.0793
Error (T*R*V*G*L*F)	56	5950.8569		
T*C*V*G*L*F	1	3831.7458	0.53	0.4726
Error (T*C*V*G*L*F)	28	7226.5353		
R*C*V*G*L*F	2	11015.3687	1.97	0.1492
(R*C*V*G*L*F)	56	5596.4935		
T*R*C*V*HG*L*F	2	120.8353	0.02	0.9788
Error (T*R*C*V*G*L*F)	56	5645.0583		

Table 4. Analysis of Variance on Accuracy Rates in Experiment 1.

Source	D.F.	M.S.	F	Pr
Main Effects and Interactions:				
T (Target Level)	1	0.0001	0.02	0.9013
Error (T)	47	0.0069		
R (Relative Size)	2	0.0098	1.62	0.2040
Error (R)	94	0.0061		
C (Consistency)	1	0.0313	4.35	0.0424
Error (C)	47	0.0072		
V (Visual Field)	1	0.0313	4.64	0.0364
Error (V)	47	0.0067		
G (Identity of the Global Level)	1	0.0027	0.42	0.5208
Error (G)	47	0.0064		
L (Identity of the Local Level)	1	0.0244	3.13	0.0832
Error (L)	47	0.0077		
F (Fixation Stimulus)	1	0.0053	0.96	0.3322
Error (F)	47	0.0055		
T*R	2	0.0001	0.02	0.9830
Error (T*R)	94	0.0063		
T*C	1	0.0087	2.13	0.1515
Error (T*C)	47	0.0041		
R*C	2	0.0196	3.60	0.0312
Error (R*C)	94	0.0054		
T*V	1	0.0053	0.73	0.3981
Error (T*V)	47	0.0073		
R*V	2	0.0040	0.67	0.5151
Error (R*V)	94	0.0060		

Table 4 (cont.)

Source	D.F.	M.S.	F	Pr
C*V	1	0.0009	0.17	0.6790
Error (C*V)	47	0.0056		
T*G	1	0.0244	3.54	0.0663
Error (T*G)	47	0.0069		
R*G	2	0.003	0.58	0.5620
Error (R*G)	94	0.0058		
C*G	1	0.0313	6.29	0.0156
Error (C*G)	47	0.0049		
V*G	1	0.0001	0.02	0.8858
Error (V*G)	47	0.0052		
T*L	1	0.0009	0.15	0.7004
Error (T*L)	47	0.0065		
R*L	2	0.0022	0.41	0.6670
Error (R*L)	94	0.0056		
C*L	1	0.0009	0.15	0.7004
Error (C*L)	47	0.0065		
V*L	1	0.0001	0.02	0.8858
Error (V*L)	47	0.0052		
G*L	1	0.0313	4.35	0.0424
Error (G*L)	47	0.0072		
T*F	1	0.0001	0.02	0.8980
Error (T*F)	47	0.0065		
R*F	2	0.0111	2.06	0.1326
Error (R*F)	94	0.0054		
C*F	1	0.0131	1.84	0.1817
Error (C*F)	47	0.0071		

Table 4 (cont.)

Source	D.F.	M.S.	F	Pr
V*F	1	0.0001	0.03	0.8597
Error (V*F)	47	0.0034		
G*F	1	0.0313	3.88	0.0548
Error (G*F)	47	0.0080		
L*F	1	0.0791	12.79	0.0008
Error (L*F)	47	0.0061		
T*R*C	2	0.0081	1.32	0.2708
Error (T*R*C)	94	0.0061		
T*R*V	2	0.0020	0.34	0.7121
Error (T*R*V)	94	0.0060		
T*C*V	1	0.0053	0.73	0.3981
Error (T*C*V)	47	0.0073		
R*C*V	2	0.0003	0.05	0.9544
Error (R*C*V)	94	0.0069		
T*R*G	2	0.0100	1.54	0.2194
Error (T*R*G)	94	0.0065		
T*C*G	1	0.0001	0.02	0.8980
Error (T*C*G)	47	0.0065		
R*C*G	2	0.0014	0.22	0.7994
Error (R*C*G)	94	0.0062		
T*V*G	1	0.0313	5.78	0.0202
Error (T*V*G)	47	0.0054		
R*V*G	2	0.0014	0.22	0.8055
Error (R*V*G)	94	0.0065		
C*V*G	1	0.0009	0.19	0.6664
Error (C*V*G)	47	0.0051		

Table 4 (cont.)

Source	D.F.	M.S.	F	Pr
T*R*L	2	0.0029	0.38	0.6881
Error (T*R*L)	94	0.0078		
T*C*L	1	0.0183	4.19	0.0462
Error (T*C*L)	47	0.0043		
R*C*L	2	0.0068	1.35	0.2642
Error (R*C*L)	94	0.0050		
T*V*L	1	0.0053	0.77	0.3834
Error (T*V*L)	47	0.0068		
R*V*L	2	0.0020	0.35	0.7030
Error (R*V*L)	94	0.0058		
C*V*L	1	0.0009	0.23	0.6359
Error (C*V*L)	47	0.0043		
T*G*L	1	0.1329	22.43	0.0001
Error (T*G*L)	47	0.0059		
R*G*L	2	0.0040	0.62	0.5390
Error (R*G*L)	94	0.0064		
C*G*L	1	0.0478	9.43	0.0035
Error (C*G*L)	47	0.0050		
V*G*L	1	0.0053	0.65	0.4247
Error (V*G*L)	47	0.0081		
T*R*F	2	0.0027	0.42	0.6592
Error (T*R*F)	94	0.0064		
T*C*F	1	0.0001	0.02	0.8980
Error (T*C*F)	47	0.0065		
R*C*F	2	0.0014	0.23	0.7929
Error (R*C*F)	94	0.0060		

Table 4 (cont.)

Source	D.F.	M.S.	F	Pr
T*V*F	1	0.0009	0.12	0.7258
Error (T*V*F)	47	0.0078		
R*V*F	2	0.0170	2.66	0.0750
Error (R*V*F)	94	0.0063		
C*V*F	1	0.0027	0.64	0.4291
Error (C*V*F)	47	0.0042		
T*G*F	1	0.0244	3.78	0.0579
Error (T*G*F)	47	0.0064		
R*G*F	2	0.0085	1.18	0.3107
Error (R*G*F)	94	0.0072		
C*G*F	1	0.0183	2.78	0.1020
Error (C*G*F)	47	0.0065		
V*G*F	1	0.0053	0.83	0.3676
Error (V*G*F)	47	0.0064		
T*L*F	1	0.0027	0.39	0.5344
Error (T*L*F)	47	0.0069		
R*L*F	2	0.0244	4.56	0.0129
Error (R*L*F)	94	0.0053		
C*L*F	1	0.0001	0.02	0.9013
Error (C*L*F)	47	0.0069		
V*L*F	1	0.0001	0.02	0.8904
Error (V*L*F)	47	0.0056		
G*L*F	1	0.0183	2.61	0.1131
Error (G*L*F)	47	0.0070		
T*R*C*V	2	0.0053	0.73	0.4860
Error (T*R*C*V)	94	0.0073		

Table 4 (cont.)

Source	D.F.	M.S.	F	Pr
T*R*C*G	2	0.0046	0.81	0.4488
Error (T*R*C*G)	94	0.0057		
T*R*V*G	2	0.0463	7.20	0.0012
Error (T*R*V*G)	94	0.0064		
T*C*V*G	1	0.0087	1.49	0.2287
Error (T*C*V*G)	47	0.0059		
R*C*V*G	2	0.0042	0.66	0.5211
Error (R*C*V*G)	94	0.0064		
T*R*C*L	2	0.0014	0.23	0.7929
Error (T*R*C*L)	94	0.0060		
T*R*V*L	2	0.0105	1.73	0.1833
Error (T*R*V*L)	94	0.0060		
T*C*V*L	1	0.0244	4.38	0.0418
Error (T*C*V*L)	47	0.0055		
R*C*V*L	2	0.0244	3.43	0.0366
Error (R*C*V*L)	94	0.0071		
T*R*G*L	2	0.0020	0.34	0.7121
Error (T*R*G*L)	94	0.0060		
T*C*G*L	1	0.0912	13.39	0.0006
Error (T*C*G*L)	47	0.0068		
R*C*G*L	2	0.0185	3.26	0.0430
Error (R*C*G*L)	94	0.0057		
T*V*G*L	1	0.0087	1.21	0.2761
Error (T*V*G*L)	47	0.0072		
R*V*G*L	2	0.0007	0.10	0.9053
Error (R*V*G*L)	94	0.0076		

Table 4 (cont.)

Source	D.F.	M.S.	F	Pr
C*V*G*L	1	0.0009	0.17	0.6790
Error (C*V*G*L)	47	0.0056		
T*R*C*F	2	0.0111	1.77	0.1753
Error (T*R*C*F)	94	0.0063		
T*R*V*F	2	0.0042	0.73	0.4838
Error (T*R*V*F)	94	0.0057		
T*C*V*F	1	0.0391	6.37	0.0150
Error (T*C*V*F)	47	0.0061		
R*C*V*F	2	0.0189	2.62	0.0780
Error (R*C*V*F)	94	0.0072		
T*R*G*F	2	0.0087	1.61	0.2057
Error (T*R*G*F)	94	0.0054		
T*C*G*F	1	0.0087	1.75	0.1922
Error (T*C*G*F)	47	0.0050		
R*C*G*F	2	0.0443	7.35	0.0011
Error (R*C*G*F)	94	0.0060		
T*V*G*F	1	0.0027	0.42	0.5208
Error (T*V*G*F)	47	0.0064		
R*V*G*F	2	0.0027	0.47	0.6287
Error (R*V*G*F)	94	0.0058		
C*V*G*F	1	0.0009	0.17	0.6790
Error (C*V*G*F)	47	0.0056		
T*R*L*F	2	0.0098	1.62	0.2040
Error (T*R*L*F)	94	0.0061		
T*C*L*F	1	0.0009	0.16	0.6903
Error (T*C*L*F)	47	0.0060		

Table 4 (cont.)

Source	D.F.	M.S.	F	Pr
R*C*L*F	2	0.0007	0.12	0.8866
Error (R*C*L*F)	94	0.0063		
T*V*L*F	1	0.0131	2.10	0.1542
Error (T*V*L*F)	47	0.0062		
R*V*L*F	2	0.0046	0.57	0.5685
Error (R*V*L*F)	94	0.0082		
C*V*L*F	1	0.0027	0.48	0.4896
Error (C*V*L*F)	47	0.0055		
T*G*L*F	1	0.0027	0.37	0.5469
Error (T*G*L*F)	47	0.0073		
R*G*L*F	2	0.0040	0.75	0.4746
Error (R*G*L*F)	94	0.0053		
C*G*L*F	1	0.0001	0.02	0.8980
Error (C*G*L*F)	47	0.0065		
V*G*L*F	1	0.0001	0.02	0.8858
Error (V*G*L*F)	47	0.0052		
T*R*C*V*G	2	0.0022	0.38	0.6870
Error (T*R*C*V*G)	94	0.0060		
T*R*C*V*L	2	0.0042	0.63	0.5325
Error (T*R*C*V*L)	94	0.0066		
T*R*C*G*L	2	0.0053	0.89	0.4146
Error (T*R*C*G*L)	94	0.0059		
T*R*V*G*L	2	0.0022	0.42	0.6560
Error (T*R*V*G*L)	94	0.0053		
T*C*V*G*L	1	0.0001	0.02	0.8980
Error (T*C*V*G*L)	47	0.0065		

Table 4 (cont.)

Source	D.F.	M.S.	F	Pr
R*C*V*G*L	2	0.0009	0.13	0.8799
Error (R*C*V*G*L)	94	0.0076		
T*R*C*V*F	2	0.0105	1.73	0.1833
Error (T*R*C*V*F)	94	0.0060		
T*R*C*G*F	2	0.0003	0.05	0.9514
Error (T*R*C*G*F)	94	0.0065		
T*R*V*G*F	2	0.0150	2.72	0.0713
Error (T*R*V*G*F)	94	0.0055		
T*C*V*G*F	1	0.0183	3.49	0.0682
Error (T*C*V*G*F)	47	0.0052		
R*C*V*G*F	2	0.0042	0.56	0.5731
Error (R*C*V*G*F)	94	0.0075		
T*R*C*L*F	2	0.0139	1.80	0.1715
Error (T*R*C*L*F)	94	0.0077		
T*R*V*L*F	2	0.0014	0.27	0.7621
Error (T*R*V*L*F)	94	0.0051		
T*C*V*L*F	1	0.0009	0.15	0.7004
Error (T*C*V*L*F)	47	0.0065		
R*C*V*L*F	2	0.0066	0.81	0.4479
Error (R*C*V*L*F)	94	0.0081		
T*R*G*L*F	2	0.0137	2.13	0.1244
Error (T*R*G*L*F)	94	0.0064		
T*C*G*L*F	1	0.0009	0.21	0.6521
Error (T*C*G*L*F)	47	0.0047		
R*C*G*L*F	2	0.0111	1.98	0.1433
Error (R*C*G*L*F)	94	0.0056		

Table 4 (cont.)

Source	D.F.	M.S.	F	Pr
T*V*G*L*F	1	0.0027	0.53	0.4716
Error (T*V*G*L*F)	47	0.0051		
R*V*G*L*F	2	0.0020	0.40	0.6720
Error (R*V*G*L*F)	94	0.0051		
C*V*G*L*F	1	0.0009	0.14	0.7097
Error (C*V*G*L*F)	47	0.0069		
T*R*C*V*G*L	2	0.0033	0.58	0.5620
Error (T*R*C*V*G*L)	94	0.0058		
T*R*C*V*G*F	2	0.0001	0.01	0.9880
Error (T*R*C*V*G*F)	94	0.0089		
T*R*C*V*L*F	2	0.0068	1.07	0.3474
Error (T*R*C*V*L*F)	94	0.0063		
T*R*C*G*L*F	2	0.0139	2.17	0.1203
Error (T*R*C*G*L*F)	94	0.0064		
T*R*V*G*L*F	2	0.0430	7.66	0.0008
Error (T*R*V*G*L*F)	94	0.0056		
T*C*V*G*L*F	1	0.0183	3.81	0.0570
Error (T*C*V*G*L*F)	47	0.0048		
R*C*V*G*L*F	2	0.0009	0.14	0.8693
Error (R*C*V*G*L*F)	94	0.0069		
T*R*C*V*G*L*F	2	0.0072	0.94	0.3933
Error (T*R*C*V*G*L*F)	94	0.0077		

Appendix B

(Tables of Chapter 4)

Table 5. Mean RTs (msec) and Accuracy Rates (%) in Experiment 2A.

	Reaction Times & St. Dev.		Accuracy Rates and St. Dev.	
Eccentricity	Global	Local	Global	Local
0.25°	404 (SD = 33)	663 (SD = 61)	1.00 (SD = 0.00)	0.95 (SD = 0.10)
0.60°	383 (SD = 31)	453 (SD = 35)	1.00 (SD = 0.03)	0.99 (SD = 0.04)
1.20°	367 (SD = 28)	439 (SD = 37)	1.00 (SD = 0.00)	0.99 (SD = 0.05)
2.35°	360 (SD = 35)	419 (SD = 30)	1.00 (SD = 0.00)	1.00 (SD = 0.03)
3.60°	360 (SD = 27)	419 (SD = 31)	1.00 (SD = 0.02)	1.00 (SD = 0.02)
4.80°	366 (SD = 30)	424 (SD = 36)	1.00 (SD = 0.04)	1.00 (SD = 0.02)
6.00°	371 (SD = 29)	428 (SD = 24)	1.00 (SD = 0.00)	1.00 (SD = 0.03)
7.15°	385 (SD = 32)	434 (SD = 30)	0.99 (SD = 0.05)	0.98 (SD = 0.07)
8.15°	390 (SD = 32)	454 (SD = 34)	1.00 (SD = 0.00)	0.99 (SD = 0.04)
All	376 (SD = 34)	459 (SD = 81)	1.00 (SD = 0.02)	0.99 (SD = 0.04)

Table 6. Mean RTs (msec) and Accuracy Rates (%) in Experiment 2B.

Eccentricity	Reaction Times & St. Dev.		Accuracy Rates and St. Dev.	
	Similar to Global	Similar to Local	Similar to Global	Similar to Local
0.25°	408 (SD = 35)	575 (SD = 82)	1.00 (SD = 0.00)	0.95 (SD = 0.11)
0.60°	387 (SD = 31)	458 (SD = 43)	1.00 (SD = 0.00)	1.00 (SD = 0.00)
1.20°	376 (SD = 36)	448 (SD = 52)	1.00 (SD = 0.00)	1.00 (SD = 0.00)
2.35°	368 (SD = 23)	442 (SD = 48)	1.00 (SD = 0.00)	0.99 (SD = 0.06)
3.60°	374 (SD = 24)	449 (SD = 39)	1.00 (SD = 0.00)	1.00 (SD = 0.04)
4.80°	380 (SD = 25)	453 (SD = 43)	1.00 (SD = 0.00)	0.99 (SD = 0.04)
6.00°	384 (SD = 24)	459 (SD = 40)	1.00 (SD = 0.00)	0.99 (SD = 0.06)
7.15°	388 (SD = 19)	464 (SD = 44)	1.00 (SD = 0.00)	0.99 (SD = 0.04)
8.15°	404 (SD = 25)	481 (SD = 51)	1.00 (SD = 0.00)	0.99 (SD = 0.06)
All	386 (SD = 31)	470 (SD = 64)	1.00 (SD = 0.00)	0.99 (SD = 0.06)

Table 7. Mean RTs (msec) and Accuracy Rates (%) in Experiment 3A.

	Reaction Times & St. Dev.		Accuracy Rates and St. Dev.	
Eccentricity	Global	Local	Global	Local
0.25°	380 (SD = 21)	719 (SD = 74)	1.00 (SD = 0.02)	0.92 (SD = 0.13)
0.60°	368 (SD = 23)	471 (SD = 25)	1.00 (SD = 0.00)	0.99 (SD = 0.03)
1.20°	351 (SD = 15)	442 (SD = 21)	1.00 (SD = 0.00)	1.00 (SD = 0.02)
2.35°	342 (SD = 16)	420 (SD = 15)	1.00 (SD = 0.02)	1.00 (SD = 0.00)
3.60°	345 (SD = 21)	426 (SD = 21)	1.00 (SD = 0.03)	1.00 (SD = 0.00)
4.80°	351 (SD = 19)	426 (SD = 17)	1.00 (SD = 0.02)	0.99 (SD = 0.02)
6.00°	356 (SD = 15)	4437 (SD = 23)	1.00 (SD = 0.00)	0.99 (SD = 0.03)
7.15°	361 (SD = 16)	450 (SD = 27)	1.00 (SD = 0.02)	0.99 (SD = 0.05)
8.15°	373 (SD = 25)	455 (SD = 21)	1.00 (SD = 0.00)	0.99 (SD = 0.03)
All	359 (SD = 23)	472 (SD = 94)	1.00 (SD = 0.02)	0.99 (SD = 0.06)

Table 8. Mean RTs (msec) and Accuracy Rates (%) in Experiment 3B.

Reaction Times & St. Dev.		Accuracy Rates and St. Dev.		
Eccentricity	Similar to Global	Similar to Local	Similar to Global	Similar to Local
0.25°	380 (SD =22)	576 (SD = 49)	1.00 (SD = 0.00)	0.97 (SD = 0.07)
0.60°	358 (SD = 20)	468 (SD = 36)	1.00 (SD = 0.03)	1.00 (SD = 0.00)
1.20°	348 (SD = 19)	460 (SD = 30)	1.00 (SD = 0.00)	0.99 (SD = 0.03)
2.35°	342 (SD = 23)	455 (SD = 33)	1.00 (SD = 0.00)	0.99 (SD = 0.03)
3.60°	344 (SD = 22)	460 (SD = 24)	1.00 (SD = 0.00)	1.00 (SD = 0.02)
4.80°	349 (SD = 19)	469 (SD = 32)	1.00 (SD = 0.03)	0.99 (SD = 0.03)
6.00°	354 (SD = 18)	475 (SD = 30)	1.00 (SD = 0.00)	0.99 (SD = 0.03)
7.15°	366 (SD = 21)	483 (SD = 32)	1.00 (SD = 0.00)	0.99 (SD = 0.03)
8.15°	369 (SD = 21)	490 (SD = 32)	1.00 (SD = 0.00)	0.98 (SD = 0.04)
All	357 (SD = 24)	482 (SD = 48)	1.00 (SD = 0.01)	0.99 (SD = 0.04)

Table 9. Mean RTs (msec) and Accuracy Rates (%) in Experiment 4A.

Eccentricity	Reaction Times & St. Dev.		Accuracy Rates and St. Dev.	
	Global	Local	Global	Local
0.25°	355 (SD = 18)	619 (SD = 46)	0.99 (SD = 0.02)	0.94 (SD = 0.06)
0.60°	342 (SD = 9)	427 (SD = 17)	1.00 (SD = 0.01)	0.98 (SD = 0.03)
1.20°	340 (SD = 14)	413 (SD = 15)	1.00 (SD = 0.01)	0.99 (SD = 0.02)
2.35°	333 (SD = 12)	398 (SD = 10)	0.99 (SD = 0.01)	1.00 (SD = 0.00)
3.60°	337 (SD = 17)	400 (SD = 14)	1.00 (SD = 0.00)	0.99 (SD = 0.02)
4.80°	346 (SD = 11)	406 (SD = 13)	0.99 (SD = 0.02)	0.99 (SD = 0.01)
6.00°	355 (SD = 14)	406 (SD = 14)	0.99 (SD = 0.02)	0.99 (SD = 0.02)
7.15°	361 (SD = 14)	418 (SD = 15)	0.99 (SD = 0.01)	0.99 (SD = 0.02)
8.15°	365 (SD = 11)	429 (SD = 16)	0.99 (SD = 0.01)	0.99 (SD = 0.01)
All	348 (SD = 17)	435 (SD = 69)	0.99 (SD = 0.01)	0.99 (SD = 0.03)

Table 10. Mean RTs (msec) and Accuracy (%) Rates in Experiment 4B.

	Reaction Times & St. Dev.		Accuracy Rates and St. Dev.	
Eccentricity	Similar to Global	Similar to Local	Similar to Global	Similar to Local
0.25°	355 (SD =14)	515 (SD = 28)	1.00 (SD = 0.00)	0.95 (SD = 0.10)
0.60°	341 (SD = 16)	438 (SD = 20)	1.00 (SD = 0.03)	0.99 (SD = 0.04)
1.20°	335 (SD = 13)	425 (SD = 14)	1.00 (SD = 0.00)	0.99 (SD = 0.05)
2.35°	333 (SD = 10)	422 (SD = 17)	1.00 (SD = 0.00)	1.00 (SD = 0.03)
3.60°	342 (SD = 15)	431 (SD = 18)	1.00 (SD = 0.02)	1.00 (SD = 0.02)
4.80°	346 (SD = 17)	442 (SD = 20)	1.00 (SD = 0.04)	1.00 (SD = 0.02)
6.00°	354 (SD = 17)	445 (SD = 19)	1.00 (SD = 0.00)	1.00 (SD = 0.03)
7.15°	356 (SD = 16)	450 (SD = 17)	0.99 (SD = 0.05)	0.98 (SD = 0.07)
8.15°	360 (SD = 14)	456 (SD = 16)	1.00 (SD = 0.00)	0.99 (SD = 0.04)
All	347 (SD = 18)	447 (SD = 33)	1.00 (SD = 0.02)	0.99 (SD = 0.04)

Table 11. Mean RTs (msec) and Accuracy Rates (%) in Experiment 5.

	REACTION TIMES AND ACCURACY RATES			
Eccentricity	Size 1.20°	Size 0.60°	Size 0.30°	Size 0.15°
	RT (SD)/ ACC(SD)	RT (SD)/ ACC (SD)	RT (SD)/ ACC (SD)	RT (SD)/ ACC (SD)
0°	368 (SD = 17) 1.00 (SD = 0.00)	397 (SD = 17) 1.00 (SD = 0.02)	449 (SD = 17) 1.00 (SD = 0.00)	504 (SD = 36) 0.98 (SD = 0.04)
1°	379 (SD = 19) 1.00 (SD = 0.02)	406 (SD = 14) 1.00 (SD = 0.00)	436 (SD = 21) 1.00 (SD = 0.00)	471 (SD = 25) 1.00 (SD = 0.02)
2°	385 (SD = 13) 0.99 (SD = 0.02)	412 (SD = 20) 1.00 (SD = 0.02)	464 (SD = 21) 0.99 (SD = 0.04)	561 (SD = 33) 0.84 (SD = 0.13)
3°	399 (SD = 17) 0.99 (SD = 0.03)	423 (SD = 19) 1.00 (SD = 0.02)	502 (SD = 26) 0.95 (SD = 0.07)	607 (SD = 39) 0.65 (SD = 0.11)
4°	414 (SD = 21) 0.99 (SD = 0.03)	444 (SD = 25) 0.99 (SD = 0.03)	563 (SD = 39) 0.80 (SD = 0.13)	631 (SD = 53) 0.57 (SD = 0.17)
5°	426 (SD = 21) 0.98 (SD = 0.03)	454 (SD = 24) 0.99 (SD = 0.03)	458 (SD = 48) 0.68 (SD = 0.14)	649 (SD = 50) 0.46 (SD = 0.16)
6°	433 (SD = 24) 0.98 (SD = 0.04)	466 (SD = 22) 0.99 (SD = 0.03)	599 (SD = 44) 0.63 (SD = 0.16)	629 (SD = 58) 0.48 (SD = 0.16)
7°	439 (SD = 21) 0.99 (SD = 0.04)	504 (SD = 30) 0.94 (SD = 0.07)	601 (SD = 38) 0.50 (SD = 0.15)	636 (SD = 45) 0.50 (SD = 0.17)
8°	450 (SD = 25) 0.99 (SD = 0.03)	518 (SD = 38) 0.89 (SD = 0.10)	632 (SD = 53) 0.58 (SD = 0.17)	647 (SD = 53) 0.47 (SD = 0.14)
All	410 (SD = 34) 0.99 (SD = 0.03)	447 (SD = 47) 0.98 (SD = 0.06)	538 (SD = 80) 0.79 (SD = 0.22)	593 (SD = 77) 0.66 (SD = 0.25)

Table 12. Mean RTs (msec) and Accuracy Rates (%) in Experiment 6.

	Reaction Times & St. Dev.		Accuracy Rates and St. Dev.	
Size (Visual Angle)	Eccentricity 7.15°	Eccentricity 2.36°	Eccentricity 7.15°	Eccentricity 2.36°
0.3°	626 (SD = 49)	461 (SD = 22)	0.53 (SD = 0.17)	0.96 (SD = 0.07)
0.6°	524 (SD = 33)	402 (SD = 19)	0.89 (SD = 0.11)	0.99 (SD = 0.03)
0.9°	468 (SD = 26)	390 (SD = 17)	0.97 (SD = 0.05)	1.00 (SD = 0.02)
1.2°	444 (SD = 21)	382 (SD = 17)	0.99 (SD = 0.03)	1.00 (SD = 0.02)
1.5°	437 (SD = 23)	375 (SD = 13)	1.00 (SD = 0.02)	0.99 (SD = 0.04)
1.8°	431 (SD = 19)	370 (SD = 18)	1.00 (SD = 0.01)	1.00 (SD = 0.01)
2.1°	428 (SD = 19)	367 (SD = 13)	0.99 (SD = 0.02)	1.00 (SD = 0.00)
All	480 (SD = 73)	392 (SD = 35)	0.91 (SD = 0.18)	0.99 (SD = 0.04)

Table 13. Analysis of Variance on RTs in Experiment 2A.

Source	D.F.	M.S.	F	Pr
Main Effects and Interactions:				
T (Target Level)	1	8945360.0127	780.90	0.0001
Error (T)	43	11455.1481		
E (Eccentricity)	8	1028900.0316	147.16	0.0001
Error (E)	344	6991.7549		
D (Direction of Opening)	1	12935.1024	2.33	0.1339
Error (D)	43	5542.9154		
F1 (First Fixation Stimulus)	1	58.5355	0.01	0.9083
Error (F1)	43	4359.9163		
F2	1	200.4622	0.05	0.8310
Error (F2)	43	4345.9270		
T*E	8	474081.4030	75.95	0.0001
Error (T*E)	344	6242.1684		
T*D	1	58966.2627	7.99	0.0071
Error (T*D)	43	7380.7379		
E*D	8	53956.7725	7.91	0.0001
Error (E*D)	344	6820.5251		
T*F1	1	3763.2084	0.84	0.3647
Error (T*F1)	43	4483.5744		
E*F1	8	7772.5266	1.44	0.1767
Error (E*F1)	344	5380.6676		
D*F1	1	8766.9206	2.41	0.1278
Error (D*F1)	43	3636.5947		
T*F2	1	14235.0077	3.97	0.0525
Error (T*F2)	43	3581.1785		

Table 13 (cont.)

Source	D.F.	M.S.	F	Pr
E*F2	8	5533.6068	1.52	0.1500
Error (E*F2)	344	3648.6079		
D*F2	1	8422.1946	2.25	0.1408
Error (D*F2)	43	3740.1270		
F1*F2	1	2471.2514	0.63	0.4314
Error (F1*F2)	43	3916.9972		
T*E*D	8	17170.4747	2.60	0.0089
Error (T*E*D)	344	6594.5676		
T*E*F1	8	5039.3665	0.95	0.4747
Error (T*E*F1)	344	5300.7375		
T*D*F1	1	1827.7160	0.25	0.6187
Error (T*D*F1)	43	7274.1698		
E*D*F1	8	38972.0061	8.74	0.0001
Error (E*D*F1)	344	4456.7769		
T*E*F2	8	4982.7509	1.10	0.3659
Error (T*E*F2)	344	4550.0563		
T*D*F2	1	179.6857	0.05	0.8319
Error (T*D*F2)	43	3937.8398		
E*D*F2	8	12319.1168	3.12	0.0021
Error (E*D*F2)	344	3951.3494		
T*F1*F2	1	22572.2350	4.44	0.0410
Error (T*F1*F2)	43	5084.8225		
E*F1*F2	8	16699.6864	3.78	0.0003
Error (E*F1*F2)	344	4412.0921		
D*F1*F2	1	5406.8196	1.32	0.2574
Error (D*F1*F2)	43	4104.4297		

Table 13 (cont.)

Source	D.F.	M.S.	F	Pr
T*E*D*F1	8	31542.4287	6.81	0.0001
Error (T*E*D*F1)	344	4630.2706		
T*E*D*F2	8	8220.8004	1.90	0.0597
Error (T*E*D*F2)	344	4335.8963		
T*E*F1*F2	8	15160.6437	3.26	0.0013
Error (T*E*F1*F2)	344	4647.0648		
T*D*F1*F2	1	8334.7994	3.04	0.0884
Error (T*D*F1*F2)	43	2741.6970		
E*D*F1*F2	8	1334.7368	0.32	0.9567
Error (E*D*F1*F2)	344	4122.0032		
T*E*D*F1*F2	8	4150.1591	0.93	0.4877
Error (T*E*D*F1*F2)	344	4440.1541		
Simple Main Effects:				
T at E1	1	3004022.1482	2178.81	0.0001
Error (T at E1)	14	1378.74		
T at E2	1	222959.59	322.73	0.0001
Error (T at E2)	14	690.86		
T at E3	1	231630.47	210.87	0.0001
Error (T at E3)	14	1098.46		
T at E4	1	1547700.27	253.68	0.0001
Error (T at E4)	14	609.83		
T at E5	1	157347.61	161.84	0.0001
Error (T at E5)	14	972.24		
T at E6	1	147757.44	89.59	0.0001
Error (T at E6)	14	1649.21		

Table 13 (cont.)

Source	D.F.	M.S.	F	Pr
T at E7	1	145719.57	196.16	0.0001
Error (T at E7)	14	743.10		
T at E8	1	106404.29	197.12	0.0001
Error (T at E8)	14	539.80		
T at E9	1	187406.34	126.40	0.0001
Error (T at E9)	14	1482.64		

Table 14. Analysis of Variance on Accuracy Rates in Experiment 2A.

Source	D.F.	M.S.	F	Pr
Main Effects and Interactions:				
T (Target Level)	1	0.0964	12.97	0.0008
Error (T)	44	0.0074		
E (Eccentricity)	8	0.0270	4.53	0.0001
Error (E)	352	0.0059		
D (Direction of Opening)	1	0.0038	0.67	0.4172
Error (D)	44	0.0057		
F1 (First Fixation stimulus)	1	0.0013	0.17	0.6851
Error (F1)	44	0.0083		
F2	1	0.0038	0.50	0.4812
Error (F2)	44	0.0076		
T*E	8	0.0283	4.37	0.0001
Error (T*E)	352	0.0064		
T*D	1	0.0445	8.17	0.0065
Error (T*D)	44	0.0054		
E*D	8	0.0094	1.27	0.2570
Error (E*D)	352	0.0074		
T*F1	1	0.0001	0.02	0.8883
Error (T*F1)	44	0.0077		
E*F1	8	0.0069	0.97	0.4573
Error (E*F1)	352	0.0071		
D*F1	1	0.0001	0.02	0.8779
Error (D*F1)	44	0.0064		
T*F2	1	0.0001	0.02	0.8835
Error (T*F2)	44	0.0070		

Table 14 (cont.)

Source	D.F.	M.S.	F	Pr
E*F2	8	0.0052	0.80	0.6019
Error (E*F2)	352	0.0065		
D*F2	1	0.0013	0.24	0.6273
Error (D*F2)	44	0.0058		
F1*F2	1	0.0038	0.47	0.4984
Error (F1*F2)	44	0.0082		
T*E*D	8	0.0105	1.45	0.1749
Error (T*E*D)	352	0.0072		
T*E*F1	8	0.0022	0.31	0.9638
Error (T*E*F1)	352	0.0073		
T*D*F1	1	0.0186	3.45	0.0700
Error (T*D*F1)	44	0.0054		
E*D*F1	8	0.0091	1.25	0.2673
Error (E*D*F1)	352	0.0073		
T*E*F2	8	0.0077	1.19	0.3063
Error (T*E*F2)	352	0.0065		
T*D*F2	1	0.0001	0.03	0.8641
Error (T*D*F2)	44	0.0052		
E*D*F2	8	0.0104	1.56	0.1349
Error (E*D*F2)	352	0.0066		
T*F1*F2	1	0.0445	5.59	0.0226
Error (T*F1*F2)	44	0.0079		
E*F1*F2	8	0.0101	1.59	0.1265
Error (E*F1*F2)	352	0.0063		
D*F1*F2	1	0.0125	2.54	0.1183
Error (D*F1*F2)	44	0.0049		

Table 14 (cont.)

Source	D.F.	M.S.	F	Pr
T*E*D*F1	8	0.0089	1.21	0.2934
Error (T*E*D*F1)	352	0.0074		
T*E*D*F2	8	0.0112	1.67	0.1033
Error (T*E*D*F2)	352	0.0067		
T*E*F1*F2	8	0.0084	1.34	0.2207
Error (T*E*F1*F2)	352	0.0063		
T*D*F1*F2	1	0.0013	0.24	0.6273
Error (T*D*F1*F2)	44	0.0058		
E*D*F1*F2	8	0.0083	1.23	0.2823
Error (E*D*F1*F2)	352	0.0067		
T*E*D*F1*F2	8	0.0034	0.51	0.8498
Error (T*E*D*F1*F2)	352	0.0068		

Table 15. Analysis of Variance on RTs in Experiment 2B.

Source	D.F.	M.S.	F	Pr
Main Effects and Interactions:				
T (Target Level)	1	9446748.9116	861.98	0.0001
Error (T)	43	10959.4158		
E (Eccentricity)	8	345879.8605	57.13	0.0001
Error (E)	344	6053.8549		
D (Direction of Opening)	1	22320.0227	5.16	0.0282
Error (D)	43	4325.2155		
F1 (First Fixation Stimulus)	1	5542.5309	1.53	0.2225
Error (F1)	43	3617.1326		
F2 (Second Fixation Stimulus)	1	8745.7601	2.69	0.1080
Error (F2)	43	3246.7978		
T*E	8	64829.1420	11.57	0.0001
Error (T*E)	344	5605.6233		
T*D	1	24048.9797	4.10	0.0492
Error (T*D)	43	5871.1616		
E*D	8	84210.8533	14.26	0.0001
Error (E*D)	344	5906.0487		
T*F1	1	5580.0056	1.50	0.2272
Error (T*F1)	43	3717.9078		
E*F1	8	4942.1846	1.31	0.2384
Error (E*F1)	344	3779.5644		
D*F1	1	1010.2430	0.27	0.6028
Error (D*F1)	43	3676.7188		
T*F2	1	0.9116	0.00	0.9889
Error (T*F2)	43	4670.3376		

Table 15 (cont.)

Source	D.F.	M.S.	F	Pr
E*F2	8	6118.4671	1.62	0.1189
Error (E*F2)	344	3786.6215		
D*F2	1	2405.4949	0.61	0.4377
Error (D*F2)	43	3920.3202		
F1*F2	1	1125.1420	0.35	0.5596
Error (F1*F2)	43	3254.5002		
T*E*D	8	3123.4346	0.59	0.7858
Error (T*E*D)	344	5290.6161		
T*E*F1	8	7609.5465	1.82	0.0729
Error (T*E*F1)	344	4188.7862		
T*D*F1	1	1336.5056	0.25	0.6212
Error (T*D*F1)	43	5394.5118		
E*D*F1	8	5174.2831	1.31	0.2397
Error (E*D*F1)	344	3964.6815		
T*E*F2	8	2635.3125	0.76	0.6354
Error (T*E*F2)	344	3452.4337		
T*D*F2	1	6505.1136	1.85	0.1804
Error (T*D*F2)	43	3508.6759		
E*D*F2	8	4585.2644	1.02	0.4188
Error (E*D*F2)	344	4486.1039		
T*F1*F2	1	658.1066	0.19	0.6656
Error (T*F1*F2)	43	3474.2807		
E*F1*F2	8	4551.7290	1.09	0.3702
Error (E*F1*F2)	344	4179.9873		
D*F1*F2	1	1822.3491	0.44	0.5120
Error (D*F1*F2)	43	4167.9960		

Table 15 (cont.)

Source	D.F.	M.S.	F	Pr
T*E*D*F1	8	3591.8334	1.02	0.4198
Error (T*E*D*F1)	344	3518.4714		
T*E*D*F2	8	4988.7844	1.23	0.2819
Error (T*E*D*F2)	344	4065.0310		
T*E*F1*F2	8	3409.3520	0.87	0.5417
Error (T*E*F1*F2)	344	3917.0308		
T*D*F1*F2	1	450.7733	0.11	0.7414
Error (T*D*F1*F2)	43	4086.6884		
E*D*F1*F2	8	3969.4133	1.10	0.3618
Error (E*D*F1*F2)	344	3605.2140		
T*E*D*F1*F2	8	3687.4846	0.88	0.5324
Error (T*E*D*F1*F2)	344	4184.3193		
Simple Main Effects:				
T at E1	1	1244469.48	153.35	0.0001
Error (T at E1)	14	8114.93		
T at E2	1	231125.85	326.97	0.0001
Error (T at E2)	14	706.88		
T at E3	1	232541.13	198.26	0.0001
Error (T at E3)	14	1172.91		
T at E4	1	241601.04	188.31	0.0001
Error (T at E4)	14	1282.98		
T at E5	1	249191.39	560.46	0.0001
Error (T at E5)	14	444.62		
T at E6	1	241614.37	185.60	0.0001
Error (T at E6)	14	1301.80		

Table 15 (cont.)

Source	D.F.	M.S.	F	Pr
T at E7	1	252837.41	197.55	0.0001
Error (T at E7)	14	1279.84		
T at E8	1	254492.48	307.69	0.0001
Error (T at E8)	14	827.10		
T at E9	1	264789.30	88.48	0.0001
Error (T at E9)	14	2992.68		

Table 16. Analysis of Variance on Accuracy Rates in Experiment 2B.

Source	D.F.	M.S.	F	Pr
Main Effects and Interactions:				
T (Target Level)	1	0.1680	34.57	0.0001
Error (T)	44	0.0048		
E (Eccentricity)	8	0.0171	2.82	0.0048
Error (E)	352	0.0060		
D (Direction of Opening)	1	0.0075	1.26	0.2670
Error (D)	44	0.0059		
F1 (First Fixation Stimulus)	1	0.0001	0.03	0.8598
Error (F1)	44	0.0048		
F2 (Second Fixation Stimulus)	1	0.0125	1.92	0.1726
Error (F2)	44	0.0065		
T*E	8	0.0142	2.29	0.0214
Error (T*E)	352	0.0062		
T*D	1	0.0186	3.66	0.0622
Error (T*D)	44	0.0050		
E*D	8	0.0099	1.91	0.0568
Error (E*D)	352	0.0052		
T*F1	1	0.0013	0.33	0.5695
Error (T*F1)	44	0.0042		
E*F1	8	0.0011	0.25	0.9817
Error (E*F1)	352	0.0048		
D*F1	1	0.0260	4.21	0.0462
Error (D*F1)	44	0.0061		
T*F2	1	0.0038	0.64	0.4295
Error (T*F2)	44	0.0060		

Table 16 (cont.)

Source	D.F.	M.S.	F	Pr
E*F2	8	0.0059	1.13	0.3434
Error (E*F2)	352	0.0052		
D*F2	1	0.0001	0.03	0.8749
Error (D*F2)	44	0.0061		
F1*F2	1	0.0001	0.03	0.8749
Error (F1*F2)	44	0.0061		
T*E*D	8	0.0169	3.30	0.0012
Error (T*E*D)	352	0.0051		
T*E*F1	8	0.0065	1.37	0.2091
Error (T*E*F1)	352	0.0048		
T*D*F1	1	0.0125	2.13	0.1516
Error (T*D*F1)	44	0.0058		
E*D*F1	8	0.0055	0.94	0.4831
Error (E*D*F1)	352	0.0059		
T*E*F2	8	0.0097	1.87	0.0639
Error (T*E*F2)	352	0.0052		
T*D*F2	1	0.0013	0.25	0.6176
Error (T*D*F2)	44	0.0054		
E*D*F2	8	0.0053	1.01	0.4300
Error (E*D*F2)	352	0.0053		
T*F1*F2	1	0.0013	0.25	0.6176
Error (T*F1*F2)	44	0.0054		
E*F1*F2	8	0.0095	1.60	0.1220
Error (E*F1*F2)	352	0.0059		
D*F1*F2	1	0.0001	0.03	0.8680
Error (D*F1*F2)	44	0.0055		

Table 16 (cont.)

Source	D.F.	M.S.	F	Pr
T*E*D*F1	8	0.0017	0.28	0.9711
Error (T*E*D*F1)	352	0.0061		
T*E*D*F2	8	0.0024	0.44	0.8939
Error (T*E*D*F2)	352	0.0054		
T*E*F1*F2	8	0.0038	0.62	0.7600
Error (T*E*F1*F2)	352	0.0061		
T*D*F1*F2	1	0.0013	0.29	0.5957
Error (T*D*F1*F2)	44	0.0048		
E*D*F1*F2	8	0.0116	1.95	0.0526
Error (E*D*F1*F2)	352	0.0059		
T*E*D*F1*F2	8	0.0170	2.87	0.0042
Error (T*E*D*F1*F2)	352	0.0059		

Table 17. Analysis of Variance on RTs in Experiment 3A.

Source	D.F.	M.S.	F	Pr
Main Effects and Interactions:				
T (Target Level)	1	17358764.8127	2791.20	0.0001
Error (T)	34	6219.0937		
E (Eccentricity)	8	1546549.4138	465.34	0.0001
Error (E)	272	3323.4929		
D (Direction of Opening)	1	161477.5365	39.26	0.0001
Error (D)	34	4113.1435		
F1 (First Fixation Stimulus)	1	3648.2031	1.07	0.3071
Error (F1)	34	3393.7023		
F2 (Second Fixation Stimulus)	1	1181.2698	0.25	0.6225
Error (F2)	34	4784.7191		
T*E	8	1046860.7689	276.87	0.0001
Error (T*E)	272	3781.0417		
T*D	1	38833.3531	15.11	0.0004
Error (T*D)	34	2570.3384		
E*D	8	7518.9463	2.31	0.0209
Error (E*D)	272	3260.6278		
T*F1	1	3364.6674	1.24	0.2727
Error (T*F1)	34	2707.1135		
E*F1	8	3121.6906	1.04	0.4045
Error (E*F1)	272	2995.2358		
D*F1	1	1026.0071	0.31	0.5834
Error (D*F1)	34	3346.6582		
T*F2	1	2838.0007	0.75	0.3932
Error (T*F2)	34	3794.9787		

Table 17 (cont.)

Source	D.F.	M.S.	F	Pr
E*F2	8	3418.9876	1.16	0.3220
Error (E*F2)	272	2940.9085		
D*F2	1	4.0007	0.00	0.9737
Error (D*F2)	34	3639.0465		
F1*F2	1	0.0960	0.00	0.9953
Error (F1*F2)	34	2714.5568		
T*E*D	8	3009.0656	0.73	0.6610
Error (T*E*D)	272	4096.6539		
T*E*F1	8	5633.1612	1.91	0.0593
Error (T*E*F1)	272	2956.3232		
T*D*F1	1	6878.6793	1.54	0.2233
Error (T*D*F1)	34	4469.6711		
E*D*F1	8	919.9937	0.26	0.9792
Error (E*D*F1)	272	3604.0024		
T*E*F2	8	1141.0766	0.33	0.9552
Error (T*E*F2)	272	3488.0325		
T*D*F2	1	6832.0285	2.15	0.1521
Error (T*D*F2)	34	3183.6568		
E*D*F2	8	3951.0284	1.09	0.3732
Error (E*D*F2)	272	3638.7231		
T*F1*F2	1	885.0285	0.21	0.6465
Error (E*F1*F2)	272	2806.2038		
D*F1*F2	1	9402.6698	3.55	0.0682
Error (D*F1*F2)	34	2649.3103		
T*E*D*F1	8	1072.3186	0.31	0.9624
Error (T*E*D*F1)	272	3474.6119		

Table 17 (cont.)

Source	D.F.	M.S.	F	Pr
T*E*D*F2	8	4088.0285	1.29	0.2471
Error (T*E*D*F2)	272	3161.8581		
T*E*F1*F2	8	2177.1669	0.74	0.6558
Error (T*E*F1*F2)	272	2940.5542		
T*D*F1*F2	1	98.8960	0.02	0.8767
Error (T*D*F1*F2)	34	4045.0193		
E*D*F1*F2	8	3976.4600	1.18	0.3141
Error (E*D*F1*F2)	272	3383.7714		
T*E*D*F1*F2	8	2817.4728	0.87	0.5453
Error (T*E*D*F1*F2)	272	3251.6540		
Simple Main Effects:				
T at E1	1	2583858.73	730.30	0.0001
Error (T at E1)	14	3538.10		
T at E2	1	243896.92	718.92	0.0001
Error (T at E2)	14	339.26		
T at E3	1	185127.88	582.42	0.0001
Error (T at E3)	14	317.86		
T at E4	1	138693.39	619.67	0.0001
Error (T at E4)	14	223.82		
T at E5	1	14841.28	434.40	0.0001
Error (T at E5)	14	340.33		
T at E6	1	128147.68	493.48	0.0001
Error (T at E6)	14	259.68		
T at E7	1	146896.22	393.11	0.0001
Error (T at E7)	14	373.68		

Table 17 (cont.)

Source	D.F.	M.S.	F	Pr
T at E8	1	171168.63	287.20	0.0001
Error (T at E8)	14	595.99		
T at E9	1	152499.43	248.87	0.0001
Error (T at E9)	14	612.76		

Table 18. Analysis of Variance on Accuracy Rates in Experiment 3A.

Source	D.F.	M.S.	F	Pr
Main Effects and Interactions:				
T (Target Level)	1	0.5013	55.93	0.0001
Error (T)	44	0.0089		
E (Eccentricity)	8	0.2883	28.67	0.0001
Error (E)	352	0.0100		
D (Direction of Opening)	1	0.1125	11.00	0.0018
Error (D)	44	0.0102		
F1 (First Fixation Stimulus)	1	0.0013	0.14	0.7054
Error (F1)	44	0.0095		
F2 (Second Fixation Stimulus)	1	0.0125	1.34	0.2537
Error (F2)	44	0.0093		
T*E	8	0.2868	33.68	0.0001
Error (T*E)	352	0.0085		
T*D	1	0.0445	5.18	0.0278
Error (T*D)	44	0.0086		
E*D	8	0.0604	6.27	0.0001
Error (E*D)	352	0.0096		
T*F1	1	0.0125	1.25	0.2690
Error (T*F1)	44	0.0099		
E*F1	8	0.0090	1.00	0.4390
Error (E*F1)	352	0.0090		
D*F1	1	0.0075	0.75	0.3913
Error (D*F1)	44	0.0100		
T*F2	1	0.0013	0.15	0.6958
Error (T*F2)	44	0.0089		

Table 18 (cont.)

Source	D.F.	M.S.	F	Pr
E*F2	8	0.0083	0.85	0.5584
Error (E*F2)	352	0.0097		
D*F2	1	0.0013	0.22	0.6446
Error (D*F2)	44	0.0064		
F1*F2	1	0.0038	0.40	0.5281
Error (F1*F2)	44	0.0095		
T*E*D	8	0.0550	5.83	0.0001
Error (T*E*D)	352	0.0094		
T*E*F1	8	0.0090	0.93	0.4909
Error (T*E*F1)	352	0.0096		
T*D*F1	1	0.0125	1.34	0.2537
Error (T*D*F1)	44	0.0093		
E*D*F1	8	0.0068	0.66	0.7296
Error (E*D*F1)	352	0.0104		
T*E*F2	8	0.0069	0.76	0.6425
Error (T*E*F2)	352	0.0091		
T*D*F2	1	0.0038	0.55	0.4623
Error (T*D*F2)	44	0.0070		
E*D*F2	8	0.0097	1.11	0.3536
Error (E*D*F2)	352	0.0087		
T*F1*F2	1	0.0186	1.68	0.2013
Error (T*F1*F2)	44	0.0110		
E*F1*F2	8	0.0080	0.76	0.6353
Error (E*F1*F2)	352	0.0105		
D*F1*F2	1	0.0001	0.01	0.9084
Error (D*F1*F2)	44	0.0115		

Table 18 (cont.)

Source	D.F.	M.S.	F	Pr
T*E*D*F1	8	0.0104	1.07	0.3844
Error (T*E*D*F1)	352	0.0097		
T*E*D*F2	8	0.0149	1.62	0.1180
Error (T*E*D*F2)	352	0.0092		
T*E*F1*F2	8	0.0103	0.84	0.5704
Error (T*E*F1*F2)	352	0.0123		
T*D*F1*F2	1	0.0013	0.11	0.7366
Error (T*D*F1*F2)	44	0.0121		
E*D*F1*F2	8	0.0070	0.61	0.7729
Error (E*D*F1*F2)	352	0.0117		
T*E*D*F1*F2	8	0.0055	0.45	0.8912
Error (T*E*D*F1*F2)	352	0.0123		

Table 19. Analysis of Variance on RTs in Experiment 3B.

Source	D.F.	M.S.	F	Pr
Main Effects and Interactions:				
T (Target Level)	1	23941503.6707	1577.46	0.0001
Error (T)	42	15177.2074		
E (Eccentricity)	8	409722.8110	95.72	0.0001
Error (E)	336	4280.5938		
D (Direction)	1	4823.3567	0.57	0.4530
Error (D)	42	8407.1619		
F1 (First Fixation Stimulus)	1	287.8270	0.07	0.7997
Error (F1)	42	4415.3101		
F2 (Second Fixation Stimulus)	1	359.0247	0.08	0.7778
Error (F2)	42	4449.5766		
T*E	8	128754.4228	31.79	0.0001
Error (T*E)	36	4050.3163		
T*D	1	24964.3877	3.55	0.0664
Error (T*D)	42	7028.2452		
E*D	8	2053.6975	0.46	0.8849
Error (E*D)	336	4482.2412		
T*F1	1	13125.0363	3.60	0.0646
Error (T*F1)	42	3644.0955		
E*F1	8	3060.2129	0.65	0.7359
Error (E*F1)	336	4712.6592		
D*F1	1	9.2249	0.00	0.9710
Error (D*F1)	42	6909.7629		
T*F2	1	614.7288	0.12	0.7335
Error (T*F2)	42	5231.4745		

Table 19 (cont.)

E*F2	8	7136.8517	1.72	0.0933
Error (E*F2)	336	4156.2299		
D*F2	1	907.8877	0.17	0.6781
Error (D*F2)	42	5195.5421		
F1*F2	1	4.3968	0.00	0.9782
Error (F1*F2)	42	5796.2291		
T*E*D	8	2679.0476	0.55	0.8147
Error (T*E*D)	336	4829.9984		
T*E*F1	8	3453.5595	0.66	0.7299
Error (T*E*F1)	336	5262.3505		
T*D*F1	1	2679.1552	0.82	0.3707
Error (T*D*F1)	42	3272.7864		
E*D*F1	8	5218.4284	1.09	0.3696
Error (E*D*F1)	336	4788.0844		
T*E*F2	8	2866.0464	0.58	0.7936
Error (T*E*F2)	336	4933.8051		
T*D*F2	1	5570.4342	1.31	0.2585
Error (T*D*F2)	42	4245.6118		
E*D*F2	8	3676.2896	0.78	0.6232
Error (E*D*F2)	336	4730.6691		
T*F1*F2	1	570.1939	0.09	0.7666
Error (T*F1*F2)	42	6387.7002		
E*F1*F2	8	3903.7870	0.82	0.5884
Error (E*F1*F2)	336	4781.0498		
D*F1*F2	1	5449.6900	1.61	0.2115
Error (D*F1*F2)	42	3384.6778		

Table 19 (cont.)

Source	D.F.	M.S.	F	Pr
T*E*D*F1	8	6515.4597	1.39	0.2000
Error (T*E*D*F1)	336	4690.7468		
T*E*D*F2	8	1630.5723	0.37	0.9374
Error (T*E*D*F2)	336	4441.1424		
T*E*F1*F2	8	3933.9788	0.88	0.5349
Error (T*E*F1*F2)	336	4478.6990		
T*D*F1*F2	1	3350.7792	0.83	0.3663
Error (T*D*F1*F2)	42	4017.8708		
E*D*F1*F2	8	2442.2235	0.58	0.7975
Error (E*D*F1*F2)	336	4239.3292		
T*E*D*F1*F2	8	2657.7494	0.61	0.7656
Error (T*E*D*F1*F2)	336	4324.0207		
Simple Main Effects:				
T at E1	1	859753.26	356.01	0.0001
Error (T at E1)	14	2414.98		
T at E2	1	271117.18	163.89	0.0001
Error (T at E2)	14	1654.26		
T at E3	1	282637.71	493.93	0.0001
Error (T at E3)	14	572.22		
T at E4	1	287028.09	202.60	0.0001
Error (T at E4)	14	1416.74		
T at E5	1	303054.54	378.68	0.0001
Error (T at E5)	14	800.29		
T at E6	1	320771.08	391.91	0.0001
Error (T at E6)	14	818.49		

Table 19 (cont.)

Source	D.F.	M.S.	F	Pr
T at E7	1	326848.81	455.17	0.0001
Error (T at E7)	14	718.08		
T at E8	1	305694.51	321.91	0.0001
Error (T at E8)	14	949.64		
T at E9	1	331036.20	443.06	0.0001
Error (T at E9)	14	747.16		

Table 20. Analysis of Variance on Accuracy Rates in Experiment 3B.

Source	D.F.	M.S.	F	Pr
Main Effects and Interactions:				
T (Target Level)	1	0.1580	28.41	0.0001
Error (T)	44	0.0055		
E (Eccentricity)	8	0.0236	3.90	0.0002
Error (E)	352	0.0060		
D (Direction)	1	0.0000	0.00	1.0000
Error (D)	44	0.0066		
F1 (First Fixation Stimulus)	1	0.0055	1.21	0.2782
Error (F1)	44	0.0046		
F2 (Second Fixation Stimulus)	1	0.0055	1.21	0.2782
Error (F2)	44	0.0046		
T*E	8	0.0260	4.29	0.0001
Error (T*E)	352	0.0060		
T*D	1	0.0000	0.00	1.0000
Error (T*D)	44	0.0059		
E*D	8	0.0083	1.55	0.1385
Error (E*D)	352	0.0053		
T*F1	1	0.0006	0.15	0.6995
Error (T*F1)	44	0.0040		
E*F1	8	0.0055	0.98	0.4520
Error (E*F1)	352	0.0056		
D*F1	1	0.0154	2.46	0.1241
Error (D*F1)	44	0.0062		
T*F2	1	0.0055	1.06	0.3088
Error (T*F2)	44	0.0052		

Table 20 (cont.)

Source	D.F.	M.S.	F	Pr
E*F2	8	0.0027	0.55	0.8163
Error (E*F2)	352	0.0050		
D*F2	1	0.0302	6.46	0.0146
Error (D*F2)	44	0.0046		
F1*F2	1	0.0000	0.00	1.0000
Error (F1*F2)	44	0.0047		
T*E*D	8	0.0083	1.53	0.1459
Error (T*E*D)	352	0.0054		
T*E*F1	8	0.0061	1.08	0.3795
Error (T*E*F1)	352	0.0057		
T*D*F1	1	0.0154	2.73	0.1054
Error (T*D*F1)	44	0.0056		
E*D*F1	8	0.0182	3.54	0.0006
Error (E*D*F1)	352	0.0051		
T*E*F2	8	0.0027	0.56	0.8094
Error (T*E*F2)	352	0.0049		
T*D*F2	1	0.0154	2.73	0.1054
Error (T*D*F2)	44	0.0056		
E*D*F2	8	0.0052	1.07	0.3817
Error (E*D*F2)	352	0.0048		
T*F1*F2	1	0.0000	0.00	1.0000
Error (T*F1*F2)	44	0.0053		
E*F1*F2	8	0.0083	1.70	0.0970
Error (E*F1*F2)	352	0.0049		
D*F1*F2	1	0.0000	0.00	1.0000
Error (D*F1*F2)	44	0.0053		

Table 20 (cont.)

Source	D.F.	M.S.	F	Pr
T*E*D*F1	8	0.0182	3.48	0.0007
Error (T*E*D*F1)	352	0.0052		
T*E*D*F2	8	0.0043	0.89	0.5217
Error (T*E*D*F2)	352	0.0048		
T*E*F1*F2	8	0.0083	1.73	0.0906
Error (T*E*F1*F2)	352	0.0048		
T*D*F1*F2	1	0.0024	0.42	0.5225
Error (T*D*F1*F2)	44	0.0059		
E*D*F1*F2	8	0.0041	0.66	0.7288
Error (E*D*F1*F2)	352	0.0063		
T*E*D*F1*F2	8	0.0038	0.62	0.7646
Error (T*E*D*F1*F2)	352	0.0062		

Table 21. Analysis of Variance on RTs in Experiment 4A.

Source	D.F.	M.S.	F	Pr
Main Effects and Interactions:				
T (Target Level)	1	12021246.2577	2393.64	0.0001
Error (T)	43	5022.1656		
E (Eccentricity)	8	970555.5042	193.07	0.0001
Error (E)	344	5027.0291		
D (Direction of Opening)	1	162232.9105	27.74	0.0001
Error (D)	43	5847.4030		
F1 (First Fixation Stimulus)	1	165.1718	0.03	0.8636
Error (F1)	43	5528.6592		
F2 (Second Fixation Stimulus)	1	82.0456	0.02	0.8944
Error (F2)	43	4600.8430		
T*E	8	791009.6377	167.35	0.0001
Error (T*E)	344	4726.7255		
T*D	1	5859.3196	2.09	0.1551
Error (T*D)	43	2797.7352		
E*D	8	2994.0845	0.73	0.6659
Error (E*D)	344	4107.3259		
T*F1	1	187.1718	0.06	0.8150
Error (T*F1)	43	3377.4467		
E*F1	8	2629.2464	0.59	0.7876
Error (E*F1)	344	4469.7371		
D*F1	1	10796.9446	2.27	0.1393
Error (D*F1)	43	4759.1774		
T*F2	1	9152.1819	2.22	0.1435
Error (T*F2)	43	4121.8948		

Table 21 (cont.)

Source	D.F.	M.S.	F	Pr
E*F2	8	5586.5967	1.21	0.2893
Error (E*F2)	344	4599.6329		
D*F2	1	1231.1946	0.32	0.5746
Error (D*F2)	43	3848.8758		
F1*F2	1	4164.8940	1.00	0.3223
Error (F1*F2)	43	4153.9344		
T*E*D	8	933.7798	0.22	0.9882
Error (T*E*D)	344	4342.7024		
T*E*F1	8	2900.7002	0.71	0.6861
Error (T*E*F1)	344	4107.5823		
T*D*F1	1	3470.1264	1.07	0.3060
Error (T*D*F1)	43	3233.7178		
E*D*F1	8	3621.2528	0.83	0.5775
Error (E*D*F1)	344	4368.5180		
T*E*F2	8	6240.1045	1.36	0.2153
Error (T*E*F2)	344	4605.1426		
T*D*F2	1	1061.1819	0.17	0.6779
Error (T*D*F2)	43	6067.7811		
E*D*F2	8	2944.1143	0.62	0.7630
Error (E*D*F2)	344	4766.5982		
T*F1*F2	1	3177.5834	0.68	0.4143
Error (T*F1*F2)	43	4676.2769		
E*F1*F2	8	6824.9800	1.52	0.1505
Error (E*F1*F2)	344	4504.1181		
D*F1*F2	1	1571.0266	0.41	0.5277
Error (D*F1*F2)	43	3874.5476		

Table 21 (cont.)

Source	D.F.	M.S.	F	Pr
T*E*D*F1	8	7060.8373	1.57	0.1335
Error (T*E*D*F1)	344	4506.8324		
T*E*D*F2	8	3559.4816	0.76	0.6365
Error (T*E*D*F2)	344	4670.7142		
T*E*F1*F2	8	5705.6147	1.41	0.1905
Error (T*E*F1*F2)	344	4044.1174		
T*D*F1*F2	1	5.0569	0.00	0.9739
Error (T*D*F1*F2)	43	4668.3370		
E*D*F1*F2	8	1485.9244	0.30	0.9662
Error (E*D*F1*F2)	344	4979.4632		
T*E*D*F1*F2	8	2511.1187	0.59	0.7863
Error (T*E*D*F1*F2)	344	4257.5699		
Simple Main Effects:				
T at E1	1	521994.27	474.49	0.0001
Error (T at E1)	14	1100.11		
T at E2	1	54187.50	685.96	0.0001
Error (T at E2)	14	78.99		
T at E3	1	39979.67	141.10	0.0001
Error (T at E3)	14	283.34		
T at E4	1	31471.21	201.29	0.0001
Error (T at E4)	14	156.35		
T at E5	1	30022.67	229.29	0.0001
Error (T at E5)	14	130.94		
T at E6	1	27132.67	190.40	0.0001
Error (T at E6)	14	142.50		

Table 21 (cont.)

Source	D.F.	M.S.	F	Pr
T at E7	1	19291.35	215.90	0.0001
Error (T at E7)	14	89.35		
T at E8	1	24443.56	185.28	0.0001
Error (T at E8)	14	131.93		
T at E9	1	30432.67	260.55	0.0001
Error (T at E9)	14	116.80		

Table 22. Analysis of Variance on Accuracy Rates in Experiment 4A.

Source	D.F.	M.S.	F	Pr
Main Effects and Interactions:				
T (Target Level)	1	0.1483	12.76	0.0009
Error (T)	44	0.0116		
E (Eccentricity)	8	0.0527	4.68	0.0001
Error (E)	352	0.0112		
D (Direction of Opening)	1	0.0816	7.26	0.0099
Error (D)	44	0.0112		
F1 (First Fixation Stimulus)	1	0.0001	0.02	0.8808
Error (F1)	44	0.0067		
F2 (Second Fixation Stimulus)	1	0.0038	0.45	0.5063
Error (F2)	44	0.0085		
T*E	8	0.0427	3.59	0.0005
Error (T*E)	352	0.0118		
T*D	1	0.0445	4.66	0.0363
Error (T*D)	44	0.0095		
E*D	8	0.0101	1.17	0.3137
Error (E*D)	352	0.0086		
T*F1	1	0.0186	1.84	0.1819
Error (T*F1)	44	0.0101		
E*F1	8	0.0036	0.35	0.9439
Error (E*F1)	352	0.0102		
D*F1	1	0.0013	0.14	0.7100
Error (D*F1)	44	0.0099		
T*F2	1	0.0001	0.03	0.8749
Error (T*F2)	44	0.0061		

Table 22 (cont.)

Source	D.F.	M.S.	F	Pr
E*F2	8	0.0073	0.79	0.6076
Error (E*F2)	352	0.0092		
D*F2	1	0.0347	4.78	0.0341
Error (D*F2)	44	0.0072		
F1*F2	1	0.0001	0.02	0.8981
Error (F1*F2)	44	0.0093		
T*E*D	8	0.0084	1.03	0.4138
Error (T*E*D)	352	0.0082		
T*E*F1	8	0.0033	0.32	0.9569
Error (T*E*F1)	352	0.0104		
T*D*F1	1	0.0001	0.02	0.8859
Error (T*D*F1)	44	0.0074		
E*D*F1	8	0.0034	0.38	0.9314
Error (E*D*F1)	352	0.0091		
T*E*F2	8	0.0057	0.56	0.8144
Error (T*E*F2)	352	0.0102		
T*D*F2	1	0.0260	2.32	0.1349
Error (T*D*F2)	44	0.0112		
E*D*F2	8	0.0173	1.55	0.1390
Error (E*D*F2)	352	0.0112		
T*F1*F2	1	0.0001	0.02	0.8981
Error (T*F1*F2)	44	0.0093		
E*F1*F2	8	0.0036	0.39	0.9242
Error (E*F1*F2)	352	0.0092		
D*F1*F2	1	0.0075	0.61	0.4371
Error (D*F1*F2)	44	0.0122		

Table 22 (cont.)

Source	D.F.	M.S.	F	Pr
T*E*D*F1	8	0.0084	0.84	0.5651
Error (T*E*D*F1)	352	0.0100		
T*E*D*F2	8	0.0274	2.45	0.0137
Error (T*E*D*F2)	352	0.0112		
T*E*F1*F2	8	0.0182	2.22	0.0253
Error (T*E*F1*F2)	352	0.0081		
T*D*F1*F2	1	0.0001	0.03	0.8749
Error (T*D*F1*F2)	44	0.0061		
E*D*F1*F2	8	0.0054	0.58	0.7972
Error (E*D*F1*F2)	352	0.0095		
T*E*D*F1*F2	8	0.0015	0.16	0.9957
Error (T*E*D*F1*F2)	352	0.0096		

Table 23. Analysis of Variance on RTs in Experiment 4B.

Source	D.F.	M.S.	F	Pr
Main Effects and Interactions:				
T (Target Level)	1	15509213.7700	3433.57	0.0001
Error (T)	42	4516.9409		
E (Eccentricity)	8	219485.6795	51.95	0.0001
Error (E)	336	4224.8779		
D (Direction of Opening)	1	141250.2383	32.89	0.0001
Error (D)	42	4295.2506		
F1 (First Fixation Stimulus)	1	1792.9948	0.42	0.5197
Error (F1)	42	4254.2755		
F2 (Second Fixation Stimulus)	1	2914.3255	0.97	0.3308
Error (F2)	42	3011.0659		
T*E	8	95123.2057	22.63	0.0001
Error (T*E)	336	4202.6519		
T*D	1	273.7732	0.08	0.7731
Error (T*D)	42	3252.0553		
E*D	8	2901.4567	0.81	0.5919
Error (E*D)	336	3570.6230		
T*F1	1	2805.5917	1.11	0.2975
Error (T*F1)	42	2520.9955		
E*F1	8	3337.6114	1.07	0.3868
Error (E*F1)	336	3132.0507		
D*F1	1	4430.9825	1.06	0.3089
Error (D*F1)	42	4177.0093		
T*F2	1	3030.7209	1.00	0.3220
Error (T*F2)	42	3017.1716		

Table 23 (cont.)

Source	D.F.	M.S.	F	Pr
E*F2	8	3754.2321	0.97	0.4572
Error (E*F2)	336	3859.8371		
D*F2	1	1428.4037	0.68	0.4143
Error (D*F2)	42	2100.7274		
F1*F2	1	3177.9870	0.93	0.3411
Error (F1*F2)	42	3427.8412		
T*E*D	8	5414.2009	1.49	0.1581
Error (T*E*D)	336	3624.1385		
T*E*F1	8	3054.1298	0.86	0.5522
Error (T*E*F1)	336	3559.0448		
T*D*F1	1	56.2177	0.01	0.9067
Error (T*D*F1)	42	4040.7709		
E*D*F1	8	1449.9574	0.49	0.8611
Error (E*D*F1)	336	2940.9068		
T*E*F2	8	4126.7888	1.45	0.1736
Error (T*E*F2)	336	2840.8899		
T*D*F2	1	686.6673	0.14	0.7100
Error (T*D*F2)	42	4897.9169		
E*D*F2	8	1653.3575	0.44	0.8982
Error (E*D*F2)	336	3779.3680		
T*F1*F2	1	14173.0335	3.42	0.0715
Error (T*F1*F2)	42	4144.5187		
E*F1*F2	8	4248.1327	1.27	0.2586
Error (E*F1*F2)	336	3346.8775		
D*F1*F2	1	2550.4967	0.60	0.4434
Error (D*F1*F2)	42	4260.2874		

Table 23 (cont.)

Source	D.F.	M.S.	F	Pr
T*E*D*F1	8	5216.8932	1.55	0.1385
Error (T*E*D*F1)	336	3363.0669		
T*E*D*F2	8	5295.8900	1.45	0.1735
Error (T*E*D*F2)	336	3645.1389		
T*E*F1*F2	8	3693.2185	1.13	0.3421
Error (T*E*F1*F2)	336	3267.3770		
T*D*F1*F2	1	21.6337	0.01	0.9229
Error (T*D*F1*F2)	42	2282.5355		
E*D*F1*F2	8	3144.3321	0.82	0.5817
Error (E*D*F1*F2)	336	3814.8683		
T*E*D*F1*F2	8	1755.6013	0.46	0.8822
Error (T*E*D*F1*F2)	336	3797.4540		
Simple Main Effects:				
T at E1	1	191367.20	287.42	0.0001
Error (T at E1)	14	665.80		
T at E2	1	70781.87	233.76	0.0001
Error (T at E2)	14	302.80		
T at E3	1	59738.00	464.60	0.0001
Error (T at E3)	14	128.58		
T at E4	1	58826.72	515.59	0.0001
Error (T at E4)	14	114.10		
T at E5	1	59645.07	155.17	0.0001
Error (T at E5)	14	384.38		
T at E6	1	69356.21	352.96	0.0001
Error (T at E6)	14	196.50		

Table 23 (cont.)

Source	D.F.	M.S.	F	Pr
T at E7	1	61099.24	142.64	0.0001
Error (T at E7)	14	428.36		
T at E8	1	66619.04	337.71	0.0001
Error (T at E8)	14	197.26		
T at E9	1	68704.62	887.14	0.0001
Error (T at E9)	14	77.44		

Table 24. Analysis of Variance on Accuracy Rates in Experiment 4B.

Source	D.F.	M.S.	F	Pr
Main Effects and Interactions:				
T (Target Level)	1	0.1680	26.10	0.0001
Error (T)	44	0.0064		
E (Eccentricity)	8	0.0322	3.84	0.0002
Error (E)	352	0.0084		
D (Direction of Opening)	1	0.0347	5.00	0.0305
Error (D)	44	0.0069		
F1 (First Fixation Stimulus)	1	0.0038	0.75	0.3901
Error (F1)	44	0.0051		
F2 (Second Fixation Stimulus)	1	0.0013	0.14	0.7054
Error (F2)	44	0.0095		
T*E	8	0.0114	1.34	0.2244
Error (T*E)	352	0.0085		
T*D	1	0.0186	2.55	0.1171
Error (T*D)	44	0.0073		
E*D	8	0.0128	1.58	0.1305
Error (E*D)	352	0.0081		
T*F1	1	0.0001	0.02	0.8883
Error (T*F1)	44	0.0077		
E*F1	8	0.0055	0.60	0.7789
Error (E*F1)	352	0.0093		
D*F1	1	0.0001	0.02	0.8883
Error (D*F1)	44	0.0077		
T*F2	1	0.0186	1.59	0.2137
Error (T*F2)	44	0.0117		

Table 24 (cont.)

Source	D.F.	M.S.	F	Pr
E*F2	8	0.0170	1.99	0.0463
Error (E*F2)	352	0.0085		
D*F2	1	0.0445	7.32	0.0096
Error (D*F2)	44	0.0060		
F1*F2	1	0.0260	2.53	0.1187
Error (F1*F2)	44	0.0102		
T*E*D	8	0.0148	1.83	0.0700
Error (T*E*D)	352	0.0081		
T*E*F1	8	0.0074	0.83	0.5777
Error (T*E*F1)	352	0.0089		
T*D*F1	1	0.0445	4.24	0.0453
Error (T*D*F1)	44	0.0105		
E*D*F1	8	0.0060	0.62	0.7588
Error (E*D*F1)	352	0.0097		
T*E*F2	8	0.0190	1.98	0.0477
Error (T*E*F2)	352	0.0095		
T*D*F2	1	0.0680	7.28	0.0098
Error (T*D*F2)	44	0.0093		
E*D*F2	8	0.0088	1.06	0.3896
Error (E*D*F2)	352	0.0083		
T*F1*F2	1	0.0125	1.83	0.1826
Error (T*F1*F2)	44	0.0068		
E*F1*F2	8	0.0042	0.49	0.8665
Error (E*F1*F2)	352	0.0086		
D*F1*F2	1	0.0013	0.14	0.7054
Error (D*F1*F2)	44	0.0095		

Table 24 (cont.)

Source	D.F.	M.S.	F	Pr
T*E*D*F1	8	0.0060	0.77	0.6265
Error (T*E*D*F1)	352	0.0078		
T*E*D*F2	8	0.0086	1.11	0.3587
Error (T*E*D*F2)	352	0.0078		
T*E*F1*F2	8	0.0072	0.80	0.5992
Error (T*E*F1*F2)	352	0.0090		
T*D*F1*F2	1	0.0013	0.14	0.7054
Error (T*D*F1*F2)	44	0.0095		
E*D*F1*F2	8	0.0072	0.91	0.5108
Error (E*D*F1*F2)	352	0.0080		
T*E*D*F1*F2	8	0.0045	0.47	0.8744
Error (T*E*D*F1*F2)	352	0.0095		

Table 25. Analysis of Variance on RTs in Experiment 5.

Source	D.F.	M.S.	F	Pr
Main Effects and Interactions:				
S (Stimulus Size)	3	17407345.7608	1541.88	0.0001
Error (S)	414	11289.6590		
E (Eccentricity)	8	2977030.9271	446.87	0.0001
Error (E)	1104	6661.9323		
D (Direction of Opening)	1	15875.9017	2.26	0.1354
Error (D)	138	7037.4796		
S*E	24	202062.0099	29.79	0.0001
Error (S*E)	3312	6783.9978		
S*D	3	2546.5732	0.35	0.7857
Error (S*D)	414	7176.4171		
E*D	8	5235.3932	0.73	0.6613
Error (E*D)	1104	7130.5463		
S*E*D	24	7049.9930	1.07	0.3756
Error (S*E*D)	3312	6615.1080		
Separate Analysis on Fixation Stimuli:				
F1 (First Fixation Stimulus)	1	7256.5000	0.62	0.4324
Error(F1)	2687	11771.3873		
F2 (Second Fixation Stimulus)	1	20078.5201	1.72	0.1900
Error(F2)	2687	11683.3542		
F1*F2	1	6752.9242	0.55	0.4567
Error(F1*F2)	2687	12186.1705		

Table 26. Analysis of Variance on Accuracy Rates in Experiment 5.

Source	D.F.	M.S.	F	Pr
Main Effects and Interactions:				
S	3	68.1446	719.37	0.0001
Error (S)	447	0.0947		
E	8	14.3159	144.85	0.0001
Error (E)	1192	0.0988		
D	1	0.1200	1.53	0.2175
Error (D)	149	0.0782		
S*E	24	4.2508	47.18	0.0001
Error (S*E)	3576	0.0901		
S*D	3	0.0661	0.97	0.4046
Error (S*D)	447	0.0679		
E*D	8	0.0741	0.89	0.5225
Error (E*D)	1192	0.0831		
S*E*D	24	0.0686	0.86	0.6628
Error (S*E*D)	3576	0.0800		
Analysis on Fixation Stimuli:				
F1 (First Fixation Stimulus)	1	0.0833	0.71	0.3992
Error(F1)	2699	0.1172		
F2 (Second Fixation Stimulus)	1	0.0033	0.03	0.8624
Error(F2)	2699	0.1109		
F1*F2	1	0.0948	0.86	0.3537
Error(F1*F2)	2699	0.1101		

Table 27. Analysis of Variance on RTs in Experiment 6.

Source	D.F.	M.S.	F	Pr
Main Effects and Interactions:				
S (Size)	1	3005999.9028	163.91	0.0001
Error (S)	43	18339.5722		
E (Eccentricity)	6	1247629.4682	89.55	0.0001
Error (E)	258	13932.1949		
D (Direction)	1	234.5018	0.02	0.8784
Error (D)	43	9904.6612		
F1 (First Fixation Stimulus)	1	1656.3411	0.36	0.5518
Error (F1)	43	4604.4474		
F2 (Second Fixation Stimulus)	1	2707.8752	0.65	0.4247
Error (F2)	43	4167.9815		
S*E	6	1258666.2427	157.47	0.0001
Error (S*E)	258	7993.2179		
S*D	1	191738.2550	37.08	0.0001
Error (S*D)	43	5171.1113		
E*D	6	153008.9857	14.62	0.0001
Error (E*D)	258	10464.1708		
S*F1	1	10592.6592	2.96	0.0924
Error (S*F1)	43	3575.3943		
E*F1	6	6379.2625	1.24	0.2845
Error (E*F1)	258	5130.5127		
D*F1	1	7752.5894	1.50	0.2280
Error (D*F1)	43	5184.2946		
S*F2	1	16.2518	0.01	0.9423
Error (S*F2)	43	3069.9918		

Table 27 (cont.)

Source	D.F.	M.S.	F	Pr
E*F2	6	1829.2293	0.50	0.8070
Error (E*F2)	258	3647.2886		
D*F2	1	1011.8281	0.20	0.6558
Error (D*F2)	43	5023.2060		
F1*F2	1	7454.4888	1.67	0.2026
Error (F1*F2)	43	4452.9630		
S*E*D	6	40964.3081	4.03	0.0007
Error (S*E*D)	258	10171.7918		
S*E*F1	6	9962.8695	1.89	0.0826
Error (S*E*F1)	258	5266.1002		
S*D*F1	1	138.7842	0.03	0.8670
Error (S*D*F1)	43	4890.9337		
E*D*F1	6	3805.9247	0.85	0.5326
Error (E*D*F1)	258	4478.8260		
S*E*F2	6	1493.0501	0.35	0.9080
Error (S*E*F2)	258	4233.0173		
S*D*F2	1	6234.7502	1.23	0.2741
Error (S*D*F2)	43	5081.0292		
E*D*F2	6	1935.2381	0.45	0.8475
Error (E*D*F2)	258	4339.5496		
S*F1*F2	1	13442.2323	2.42	0.1274
Error (S*F1*F2)	43	5561.8386		
E*F1*F2	6	5494.4007	1.07	0.3839
Error (E*F1*F2)	258	5158.4714		
D*F1*F2	1	85.4709	0.02	0.8790
Error (D*F1*F2)	43	3645.8098		

Table 27 (cont.)

Source	D.F.	M.S.	F	Pr
S*E*D*F1	6	5617.4140	1.30	0.2571
Error (S*E*D*F1)	258	4318.4894		
S*E*D*F2	6	3270.4395	0.85	0.5305
Error (S*E*D*F2)	258	3836.3509		
S*E*F1*F2	6	3083.3289	0.67	0.6766
Error (S*E*F1*F2)	258	4623.9260		
S*D*F1*F2	1	1482.5911	0.31	0.5785
Error (S*D*F1*F2)	43	4731.2098		
E*D*F1*F2	6	3322.6111	0.70	0.6502
Error (E*D*F1*F2)	258	4749.4766		
S*E*D*F1*F2	6	1327.0163	0.29	0.9404
Error (S*E*D*F1*F2)	258	4544.9766		

Table 28. Analysis of Variance on Accuracy Rates in Experiment 6.

Source	D.F.	M.S.	F	Pr
Main Effects and Interactions:				
S (Size)	1	0.0049	0.05	0.8192
Error (S)	44	0.0938		
E (Eccentricity)	6	3.5330	47.45	0.0001
Error (E)	264	0.0744		
D (Direction)	1	0.0446	0.88	0.3533
Error (D)	44	0.0507		
F1 (First Fixation Stimulus)	1	0.0240	0.48	0.4902
Error (F1)	44	0.0495		
F2 (Second Fixation Stimulus)	1	0.0097	0.18	0.6733
Error (F2)	44	0.0539		
S*E	6	5.0220	66.14	0.0001
Error (S*E)	264	0.0759		
S*D	1	1.2382	27.70	0.0001
Error (S*D)	44	0.0447		
E*D	6	0.4756	7.00	0.0001
Error (E*D)	264	0.0679		
S*F1	1	0.0017	0.05	0.8309
Error (S*F1)	44	0.0387		
E*F1	6	0.0105	0.28	0.9469
Error (E*F1)	264	0.0380		
D*F1	1	0.0001	0.00	0.9501
Error (D*F1)	44	0.0501		
S*F2	1	0.1446	3.26	0.0779
Error (S*F2)	44	0.0443		

Table 28 (cont.)

Source	D.F.	M.S.	F	Pr
E*F2	6	0.0425	0.96	0.4505
Error (E*F2)	264	0.0442		
D*F2	1	0.2160	5.47	0.0240
Error (D*F2)	44	0.0395		
F1*F2	1	0.0017	0.04	0.8420
Error (F1*F2)	44	0.0443		
S*E*D	6	0.2220	3.84	0.0011
Error (S*E*D)	264	0.0578		
S*E*F1	6	0.0263	0.76	0.6056
Error (S*E*F1)	264	0.0348		
S*D*F1	1	0.0001	0.00	0.9475
Error (S*D*F1)	44	0.0452		
E*D*F1	6	0.0478	1.29	0.2633
Error (E*D*F1)	264	0.0371		
S*E*F2	6	0.0358	0.77	0.5921
Error (S*E*F2)	264	0.0463		
S*D*F2	1	0.1446	3.82	0.0571
Error (S*D*F2)	44	0.0379		
E*D*F2	6	0.0600	1.59	0.1514
Error (E*D*F2)	264	0.0378		
S*F1*F2	1	0.0160	0.58	0.4514
Error (S*F1*F2)	44	0.0278		
E*F1*F2	6	0.0050	0.14	0.9911
Error (E*F1*F2)	264	0.0362		
D*F1*F2	1	0.0716	2.54	0.1182
Error (D*F1*F2)	44	0.0282		

Table 28 (cont.)

Source	D.F.	M.S.	F	Pr
S*E*D*F1	6	0.0321	0.82	0.5570
Error (S*E*D*F1)	264	0.0393		
S*E*D*F2	6	0.1043	2.86	0.0102
Error (S*E*D*F2)	264	0.0364		
S*E*F1*F2	6	0.0054	0.14	0.9903
Error (S*E*F1*F2)	264	0.0380		
S*D*F1*F2	1	0.0001	0.01	0.9414
Error (S*D*F1*F2)	44	0.0363		
E*D*F1*F2	6	0.0156	0.41	0.8750
Error (E*D*F1*F2)	264	0.0384		
S*E*D*F1*F2	6	0.0173	0.45	0.8429
Error (S*E*D*F1*F2)	264	0.0382		

Appendix C

(Tables of Chapter 5)

Table 29. Mean RTs (msec) and Accuracies Rates (%) to Consistent and Inconsistent Stimuli in Experiment 7.

REACTION TIMES AND ACCURACY RATES				
Eccentricity	Global (Consist.) RT(SD)/ ACC(SD)	Global (Inconsist.) RT(SD)/ ACC(SD)	Local (Consist.) RT(SD)/ ACC(SD)	Local (Inconsist.) RT(SD)/ ACC(SD)
0.25°	392 (SD = 54) 0.99 (SD = 0.07)	404 (SD = 80) 1.00 (SD = 0.00)	660 (SD = 101) 0.97 (SD = 0.16)	734 (SD = 174) 0.86 (SD = 0.41)
0.60°	375 (SD = 62) 0.99 (SD = 0.07)	369 (SD = 53) 0.99 (SD = 0.10)	470 (SD = 92) 1.00 (SD = 0.00)	488 (SD = 75) 0.99 (SD = 0.10)
1.20°	348 (SD = 45) 0.99 (SD = 0.07)	344 (SD = 37) 1.00 (SD = 0.00)	442 (SD = 80) (SD = 0.10)	466 (SD = 73) 0.98 (SD = 0.12)
2.35°	349 (SD = 64) 1.00 (SD = 0.00)	349 (SD = 60) 1.00 (SD = 0.00)	439 (SD = 79) 1.00 (SD = 0.00)	437 (SD = 48) 0.98 (SD = 0.14)
3.60°	353 (SD = 47) 1.00 (SD = 0.00)	352 (SD = 40) 0.99 (SD = 0.10)	446 (SD = 89) 0.99 (SD = 0.07)	439 (SD = 50) 0.99 (SD = 0.10)
4.80°	351 (SD = 55) 1.00 (SD = 0.00)	359 (SD = 63) 1.00 (SD = 0.00)	450 (SD = 73) 1.00 (SD = 0.00)	447 (SD = 53) 0.98 (SD = 0.14)
6.00°	359 (SD = 38) 1.00 (SD = 0.00)	361 (SD = 47) 0.99 (SD = 0.07)	457 (SD = 69) 0.99 (SD = 0.10)	449 (SD = 51) 0.99 (SD = 0.10)
7.15°	363 (SD = 47) 0.99 (SD = 0.07)	363 (SD = 68) 1.00 (SD = 0.00)	463 (SD = 68) 0.98 (SD = 0.14)	454 (SD = 56) 0.98 (SD = 0.12)
8.15°	375 (SD = 71) 1.00 (SD = 0.00)	364 (SD = 42) 0.99 (SD = 0.07)	509 (SD = 107) 0.96 (SD = 0.19)	461 (SD = 53) 0.99 (SD = 0.10)
All	362 (SD = 57) 1.00 (SD = 0.05)	363 (SD = 59) 0.98 (SD = 0.06)	481 (SD = 107) 0.99 (SD = 0.11)	487 (SD = 120) 0.97 (SD = 0.18)

Table 30. Analysis of Variance on RTs in Experiment 7.

Source	D.F.	M.S.	F	Pr
Main Effects and Interactions:				
T (Target Level)	1	9989140.6310	1061.42	0.0001
Error (T)	36	9411.1178		
E (Eccentricity)	8	712934.8556	169.62	0.0001
Error (E)	288	4203.1322		
C (Consistency)	1	7774.6250	2.14	0.1520
Error (C)	36	3629.8634		
D (Direction of Opening)	1	3439.4628	0.74	0.3964
Error (D)	36	4669.1966		
T*E	8	356689.0634	79.75	0.0001
Error (T*E)	288	4472.5798		
T*C	1	10381.7871	2.38	0.1318
Error (T*C)	36	4364.6413		
E*C	8	41913.5608	10.42	0.0001
Error (E*C)	288	4020.8843		
T*D	1	46.7751	0.01	0.9203
Error (T*D)	36	4610.8746		
E*D	8	9884.0641	2.40	0.0160
Error (E*D)	288	4114.1434		
C*D	1	18556.6670	4.51	0.0406
Error (C*D)	36	4112.4070		
T*E*C	8	15441.2449	4.45	0.0001
Error (T*E*C)	288	3472.8490		
T*E*D	8	6081.7126	1.28	0.2542
Error (T*E*D)	288	4755.7357		

Table 30 (cont.)

Source	D.F.	M.S.	F	Pr
T*C*D	1	20884.6400	3.49	0.0698
Error (T*C*D)	36	5981.2518		
E*C*D	8	3733.3748	1.06	0.3900
Error (E*C*D)	288	3516.1460		
T*E*C*D	8	2822.5116	0.64	0.7400
Error (T*E*C*D)	288	4379.8995		
Analysis on Fixation Stimuli:				
AZ	1	0.3061	1.12	0.2891
Error(AZ)	1727	0.2722		
BZ	1	0.0700	0.29	0.5891
Error(BZ)	1727	0.2399		
AZ*BZ	1	0.2800	1.08	0.2979
Error(AZ*BZ)	1727	0.2583		
Simple Main Effects:				
C at T1 & E1	1	13159.20	2.15	0.1628
Error (C at T1 & E1)	14	6107.36		
C at T1 & E2	1	2603.23	1.67	0.2164
Error (C at T1 & E2)	14	1562.67		
C at T1 & E3	1	1161.99	1.25	0.2808
Error (C at T1 & E3)	14	928.19		
C at T1 & E4	1	0.47	0.00	0.9899
Error (C at T1 & E4)	14	2806.09		
C at T1 & E5	1	138.84	0.07	0.7905
Error (C at T1 & E5)	14	1897.70		

Table 30 (cont.)

Source	D.F.	M.S.	F	Pr
C at T1 & E6	1	5306.65	1.60	0.2252
Error (C at T1 & E6)	14	3316.44		
C at T1 & E7	1	169.56	0.25	0.6259
Error (C at T1 & E7)	14	684.39		
C at T1 & E8	1	4.59	0.00	0.9657
Error (C at T1 & E8)	14	2402.73		
C at T1 & E9	1	10788.88	3.90	0.0670
Error (C at T1 & E9)	14	2766.40		
C at T2 & E1	1	527478.54	20.51	0.0004
Error (C at T2 & E1)	14	25723.01		
C at T2 & E2	1	32590.56	4.76	0.0455
Error (C at T2 & E2)	14	6846.97		
C at T2 & E3	1	53692.17	11.17	0.0045
Error (C at T2 & E3)	14	4807.68		
C at T2 & E4	1	266.11	0.04	0.8435
Error (C at T2 & E4)	14	6597.15		
C at T2 & E5	1	4793.97	0.55	0.4693
Error (C at T2 & E5)	14	8699.26		
C at T2 & E6	1	1016.12	0.31	0.5833
Error (C at T2 & E6)	14	3231.80		
C at T2 & E7	1	5124.71	1.29	0.2739
Error (C at T2 & E7)	14	3972.77		
C at T2 & E8	1	8995.20	2.38	0.1434
Error (C at T2 & E8)	14	3773.79		
C at T2 & E9	1	220736.82	15.11	0.0015
Error (C at T2 & E9)	14	14608.68		

Table 31. Analysis of Variance on Accuracy Rates in Experiment 7.

Source	D.F.	M.S.	F	Pr
Main Effects and Interactions:				
T (Target Level)	1	0.7089	50.01	0.0001
Error (T)	95	0.0141		
E (Eccentricity)	8	0.2044	16.84	0.0001
Error (E)	760	0.0121		
C (Consistency)	1	0.1875	14.17	0.0003
Error (C)	95	0.0132		
D (Direction of Opening)	1	0.0370	3.65	0.0590
Error (D)	95	0.0101		
T*E	8	0.2102	17.73	0.0001
Error (T*E)	760	0.0118		
T*C	1	0.1875	17.21	0.0001
Error (T*C)	95	0.0108		
E*C	8	0.1230	9.52	0.0001
Error (E*C)	760	0.0129		
T*D	1	0.0370	3.28	0.0735
Error (T*D)	95	0.0112		
E*D	8	0.0155	1.37	0.2059
Error (E*D)	760	0.0113		
C*D	1	0.0700	6.75	0.0109
Error (C*D)	95	0.0103		
T*E*C	8	0.1464	11.90	0.0001
Error (T*E*C)	760	0.0123		
T*E*D	8	0.0142	1.20	0.2959
Error (T*E*D)	760	0.0118		

Table 31 (cont.)

Source	D.F.	M.S.	F	Pr
T*C*D	1	0.0978	7.87	0.0061
Error (T*C*D)	95	0.0124		
E*C*D	8	0.0192	1.71	0.0919
Error (E*C*D)	760	0.0112		
T*E*C*D	8	0.0196	1.70	0.0956
Error (T*E*C*D)	760	0.0115		
Analysis on Fixation Stimuli:				
AZ	1	0.0833	0.34	0.5574
Error(AZ)	1727	0.2419		
BZ	1	0.2089	0.80	0.3700
Error(BZ)	1727	0.2598		
AZ*BZ	1	0.6689	2.57	0.1094
Error(AZ*BZ)	1727	0.2607		

Appendix D

(Tables of Chapter 6)

Table 32. Mean RTs (msec) and Accuracy Rates (%) in Experiment 8.

	Reaction Times & St. Dev.		Accuracy Rates and St. Dev.	
Visual angle Condition	Including (Outside Figure)	Included (Inside Figure)	Including (Outside Figure)	Included (Inside Figure)
Small	351 (SD =66)	381 (SD = 75)	0.97 (SD = 0.19)	0.98 (SD = 0.17)
Large	363 (SD = 72)	331 (SD = 70)	0.97 (SD = 0.18)	0.97 (SD = 0.22)
All	357 (SD = 69)	356 (SD = 77)	0.97 (SD = 0.19)	0.98 (SD = 0.20)

Table 33. Mean RTs (msec) and Accuracy Rates (%) in Experiment 9.

	Consistent		Inconsistent	
	RTs and Accuracy Rates and St.Devs.		RTs and Accuracy Rates and St.Devs.	
Visual angle Condition	Including (Outside figure)	Included (Inside figure)	Including (Outside figure)	Included (Inside figure)
Small	335 (SD =69) 0.98 (SD = 0.21)	359 (SD = 55) 0.98 (SD = 0.16)	343 (SD = 64) 0.97 (SD = 0.17)	381 (SD = 64) 0.90 (SD = 0.30)
Large	366 (SD = 87) 1.00 (SD = 0.16)	334 (SD = 59) 0.99 (SD = 0.14)	384 (SD = 100) 0.96 (SD = 0.27)	348 (SD = 62) 0.95 (SD = 0.22)
All	350 (SD = 78) 0.99 SD = 0.18)	346 (SD = 57) 0.98 (SD = 0.15)	363 (SD = 82) 0.96 (SD = 0.22)	364 (SD = 63) 0.92 (SD = 0.22)

Table 34. Analysis of Variance on RTs in Experiment 8.

Source	D.F.	M.S.	F	Pr
Main Effects and Interactions:				
T (Target Level)	1	1069.74	0.06	0.8156
Error (T)	20	19159.76		
V (Visual Angle)	1	267515.16	16.66	0.0006
Error (V)	20	16055.48		
D (Direction of Opening)	1	137150.85	32.16	0.0000
Error (D)	20	4264.47		
T*V	1	747748.36	45.21	0.0000
Error (T*V)	20	16538.25		
T*D	1	4013.58	1.56	0.2263
Error (T*D)	20	2575.68		
V*D	1	3969.41	0.64	0.4346
Error (V*D)	20	6243.69		
T*V*D	1	12827.90	3.72	0.0680
Error (T*V*D)	20	3445.57		
Simple Main Effects:				
T at V1	1	380524.20	20.88	0.0002
Error (T at V1)	20	18223.75		
T at V2	1	441061.21	24.18	0.0001
Error (T at V2)	20	18240.34		

Table 35. Analysis of Variance on Accuracy Rates in Experiment 8.

Source	D.F.	M.S.	F	Pr
Main Effects and Interactions:				
T (Target Level)	1	0.01	0.55	0.4679
Error (T)	20	0.02		
V (Visual Angle)	1	0.04	1.35	0.2594
Error (V)	20	0.03		
D (Direction of Opening)	1	0.01	0.34	0.5652
Error (D)	20	0.02		
T*V	1	0.07	2.43	0.1345
Error (T*V)	20	0.03		
T*D	1	0.05	2.32	0.1431
Error (T*D)	20	0.02		
V*D	1	0.06	3.11	0.0932
Error (V*D)	20	0.02		
T*V*D	1	0.00	-.07	1.0000
Error (T*V*D)	20	0.02		

Table 36. Analysis of Variance on RTs in Experiment 9.

Source	D.F.	M.S.	F	Pr
Main Effects and Interactions:				
T (Target Level)	1	6940.4149	1.40	0.2396
Error (T)	96	4955.9032		
V (Visual Angle)	1	8555.8865	2.02	0.1584
Error (V)	96	4234.5415		
C (Consistency)	1	153922.6391	56.00	0.0001
Error (C)	96	2748.7342		
D (Direction of Opening)	1	66406.6391	19.47	0.0001
Error (D)	96	3410.0962		
T*V	1	459749.3195	93.02	0.0001
Error (T*V)	96	4942.6828		
T*C	1	120.2474	0.05	0.8263
Error (T*C)	96	2484.2643		
V*C	1	1430.4768	0.43	0.5113
Error (V*C)	96	3291.3166		
T*D	1	17827.0618	6.96	0.0097
Error (T*D)	96	2560.4563		
V*D	1	26905.5695	10.02	0.0021
Error (V*D)	96	2684.1672		
C*D	1	1188.2500	0.42	0.5166
Error (C*D)	96	2803.1315		
T*V*C	1	25427.5283	8.01	0.0057
Error (T*V*C)	96	3175.2796		
T*V*D	1	14513.2190	6.46	0.0126
Error (T*V*D)	96	2247.0458		

Table 36 (cont.)

Source	D.F.	M.S.	F	Pr
T*C*D	1	9372.8067	2.52	0.1155
Error (T*C*D)	96	3715.1100		
V*C*D	1	1766.9690	0.80	0.3737
Error (V*C*D)	96	2211.8505		
T*V*C*D	1	10.5567	0.00	0.9488
Error (T*V*C*D)	96	2550.5788		

Table 37. Analysis of Variance on Accuracy Rates in Experiment 9.

Source	D.F.	M.S.	F	Pr
Main Effects and Interactions:				
T (Target Level)	1	0.0378	0.85	0.3589
Error (T)	199	0.0447		
V (Visual Angle)	1	0.0378	0.98	0.3225
Error (V)	199	0.0384		
C (Consistency)	1	1.0878	20.92	0.0001
Error (C)	199	0.0520		
D (Direction of Opening)	1	0.0078	0.19	0.6633
Error (D)	199	0.0411		
T*V	1	0.3403	8.11	0.0049
Error (T*V)	199	0.0419		
T*C	1	0.2628	5.41	0.0211
Error (T*C)	199	0.0486		
V*C	1	0.0153	0.37	0.5421
Error (V*C)	199	0.0410		
T*D	1	0.0703	1.38	0.2410
Error (T*D)	199	0.0508		
V*D	1	0.0378	1.09	0.2976
Error (V*D)	199	0.0346		
C*D	1	0.1378	3.03	0.0833
Error (C*D)	199	0.0454		
T*V*C	1	0.5778	14.18	0.0002
Error (T*V*C)	199	0.0407		
T*V*D	1	0.0078	0.20	0.6584
Error (T*V*D)	199	0.0398		

Table 36 (cont.)

Source	D.F.	M.S.	F	Pr
T*C*D	1	0.0903	2.09	0.1498
Error (T*C*D)	199	0.0432		
V*C*D	1	0.0903	2.29	0.1318
Error (V*C*D)	199	0.0394		
T*V*C*D	1	0.0253	0.54	0.4653
Error (T*V*C*D)	199	0.0472		