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Keywords

knowledge, simulation, measures, network, work, performance, intensive

Disciplines

Engineering | Science and Technology Studies

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Network Measures and Simulation for Knowledge Intensive Work Performance

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Abstract

We describe the process of designing a reliable and valid instrument for collecting network and attribute data. Here, we explore the relationship between social networks structure, information and communication technologies (ICT) use and attitude towards performance in knowledge intensive work. We first develop a model for exploring the inherent relationship between the three concepts based on existing literature. We then develop appropriate item sets for measuring different independent (network structure, ICT use) and dependent variables (performance). We use the reliable item sets along with justifications to construct different phases of our instrument. In doing so, we introduce a simulation approach where we generate synthetic dataset for performing this analysis. In conclusion, we highlight the strengths of using a simulation approach for instrument testing and validation prior to real empirical data collection. We provide some descriptive statistics to demonstrate preliminary exploration of the relationship between different independent variables and dependent variables.

Keywords: Network Instrument, Simulation, Egocentric Network, ICT use, Performance, General Practice

Introduction

The central tenet of social networks is that network structure and position have important behavioural, perceptual and attitudinal consequences for both individual units and for the system as a whole (Knoke & Kulinski, 1992). Social networks analysis (SNA) plays a vital role in exploring the patterns of interaction between individuals or groups in an enterprise and across disciplines. SNA offers useful measures and properties such as the cohesiveness of the individuals, the number of relationships (ties), the number and quality of informal subgroups (cliques), information brokers (those who contribute to information transitivity) and bottlenecks (those who hinder information transitivity). In social network studies, the relationships between actors and structural (or network) measures remain as key focus of study. Usually attribute data about actors such as demographic details, proximity of work locations, personal attitudes, years of experience in consultations and so on are analysed in conjunction with network data to reveal interesting insights. For example, Coleman et al (1957) found that doctors who had a denser social network were associated with faster rates of adoption of a new drug; Kalish and Robins (2006) associated individual psychological predispositions with network structure; Hinds et al (2006) associated density of a corporate team structure with their ease of coordination at work.

In this study, we investigate the interplay between social network structure, information and communication technology (ICT) use, and performance of knowledge-intensive workers. Studies on network structure and individual performance have been well document in previous studies (Sparrowe, Liden et al., 2001; Ahuja, Galletta et al., 2003; Cross & Cummings, 2004). We are currently observing the shift of importance in studies on technology use from impacts of ICT use on task level performance (Goodhue & Thompson, 1995) to impacts of ICT use on communication structure (Garton & Wellman, 1995; Hinds & Kiesler, 1995; Goecks & Mynatt, 2004). There is however, inadequate literature on the interaction effects between individual network structure, ICT use, and performance (Chung, Hossain et al., 2005b). The following questions motivate this research – (i) how does the

interplay between individual network structure and ICT use enhance performance attitude? (ii) to what extent does an individual's network structure impact performance attitude? (iii) to what extent does an individual's level of ICT use impact performance attitude? (iv) does ICT use moderate the inherent relationship between individual's network structure and performance attitude; and if so, to what extent?

In the following sections, we describe briefly the context of the study and proposed conceptual model, followed by the research hypotheses. Emphasis in this paper is however, on the design and development of the survey instrument for operationalising the constructs of the study followed by a discussion of its reliability and validity. It should be noted that the research is still in progress as the data collection phase is on-going at the current time of writing.

Context of the Study

Rural general practitioners (GP) of New South Wales (NSW), Australia form the sampling frame and context of our study. There are approximately 1,518 GPs in rural NSW according to the Australian Divisions of General Practice (ADGP, 2005). Rural GPs are considered knowledge intensive workers because of the nature of their work – extensive medical expertise, high patient to GP ratio, long work hours, usage of advance medical technologies, provision of diverse healthcare services and so on (Weltmore & Stewart, 2001). In knowledge intensive work, knowing where and whom to obtain information from is crucial for performance. However, the domain of general practice faces the problem of declining performance as general practitioners (GPs) age (Choudhry, Fletcher et al., 2005). This is attributed to obsolescence of technological and explicit medical knowledge and lack of peer support. Even worse, GPs generally under-utilise the potential capabilities of ICT by commonly using them for administrative purposes (White, Sheedy et al., 2002). These problems set the context of our study and highlight its importance. Therefore, we argue that high levels of ICT use and social connectedness amongst peer groups and health professionals are crucial for GPs to foster knowledge transfer and advice seeking.

Framework and Construct Development

The following section briefly describes the conceptual framework for the study, followed by a review of theoretical constructs and the research hypotheses. A diagram of the conceptual framework is depicted below.

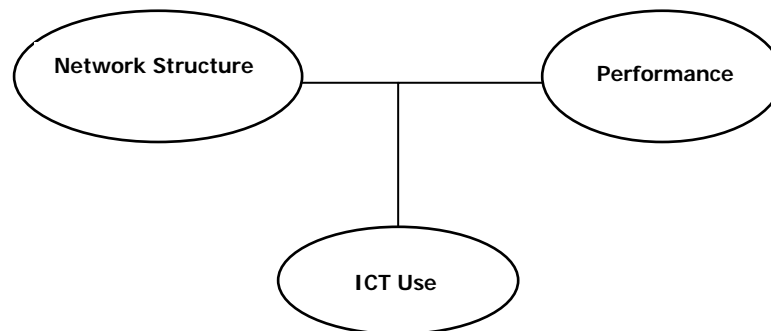


Figure 1: Conceptual Framework

Network Structure and Performance

This study focuses on relational and structural properties of social networks because they bear significant impacts on an individual's outcome such as performance. Social ties in a relation form the basis of a network structure. Ties may be regarded as strong or weak depending on several factors such as frequency of interaction, intimacy, closeness and reciprocity of exchange (Marsden & Campbell, 1984). Studies on weak ties have found that weak inter-unit ties sped up project completion times where the required information was simple, but slowed them down when knowledge to be transferred was complex (Hansen, 1999). Weak ties therefore foster search activities whereas strong ties facilitated the knowledge transfer process (Krackhardt, 1992) – the findings of which were confirmed by other studies (Levin & Cross, 2004). These findings also demonstrate support for Granovetter's (1973) theory about the strength of weak ties, which argues that as strong ties tend to bond similar people, information that originates and circulates at a high velocity amongst strongly tied clusters tends to become redundant quickly. Such network-clusters are therefore are not conducive to channels of innovation or new information. The influx of new and novel information must hence come from weak ties.

The weak tie argument may cursorily suggest that individuals should focus on maintaining a huge number of weak ties in order to capitalise on information benefits. Previous studies have shown that denser ties in an individual's social network is conducive to diffusion of innovation (Coleman, Katz et al., 1966), intellectual performance (Coleman, 1988), job performance (Shaw, 1964; Hansen, 1999; Sparrowe, Liden et al., 2001; Cross & Cummings, 2004) and knowledge-sharing (Cross & Cummings, 2004; Cummings, 2004). Burt (1992) however, takes on a structural perspective by suggesting that dense networks are far more inefficient than sparse networks because (1) they are costly to maintain, and (2) they provide redundant information.

Burt (1992) proposes the theory of 'structural holes' which is based on the idea that actors are in a better position to benefit from their interactions and transactions with others if actors are connected to others who are not connected themselves or well organised. The bridging of connection to others provides opportunities; the lack of connections among those others is the structural holes. Burt (1992) argues that an individual should be able to obtain unique and resourceful information by connecting himself to those belonging to non-redundant clusters to achieve diversity, brokerage and control advantages (figure 3). Optimisation of a social network of an individual can be measured by effectiveness and efficiency of one's personal network. Efficiency describes the channels of access offered by a primary contact (broker) in a structural hole to access all others (ie. secondary contacts) in the network. Effectiveness equates to the total number of contacts reached along with all the primary contacts. Effectiveness is hence the yield of the entire network.

In the context of medical practice, social networks have been regarded as a promising concept for becoming a unifying framework since 1970s (Erickson, 1975). To date, social network concepts and techniques have been applied in clinical and hospital settings (Anderson, 2002), for doctors and nurses to deliver better quality care (Cott, 1997; West, Barron et al., 1999) and physician utilisation of medical information systems (Anderson & Jay, 1985). In general, social networks theory and practice is regarded useful for clinical

practice in location of resources and serves as an interpreter of help-seeking behaviour and utilisation of services. Numerous studies have documented GPs' need for immediate access to information and the importance of the social network of peers and colleagues. As Dee and Blazek (1993, p. 263) maintains, "...colleagues are familiar, reliable, immediately available, and inexpensive; they give concise, organised answers that synthesize available information". The value of a social contact is hence much more profound than simply being easily accessible and dispensing accurate information because it allows GPs to socialise, to leave routine, to display personal knowledge, and to generate professional contacts (Curley, Connelly et al., 1990). In light of the arguments posited above, we anticipate the following hypotheses¹:

H1: Density of a GP's professional network structure is positively associated with performance attitudes

H2: Effectiveness of a GP's professional network structure is positively associated with performance attitudes

H3: Efficiency of a GP's professional network structure is positively associated with performance attitudes

ICT Use and Social Networks

While most social network studies have assumed ties being conducted face-to-face, we argue that such studies formally emphasise on one strand of tie – often work relations, therefore neglecting the multiplex character of personal networks, which tend precisely to intersect several social relations (Licoppe & Smoreda, 2005). ICTs are replacing traditional resources for developing an actor's social network (Nardi, Whittaker et al., 2000). Personal networks

¹ For H1, H2 and H3, age, experience as a general practitioner and experience as a rural general practitioner will be controlled for to eliminate any variance in performance attitudes. Performance attitudes will be described in the following sections.

not only shape the ICT for communication, but the ICT means are also shaping personal networks and re-drawing social boundaries. Therefore, a significant construct in the social network-performance conceptual model of this paper is '*ICT use*'. Where computer networks connect people, such networks are computer supported social networks (CSSN) (Wellman, 1996). CSSN sustain strong, intermediate, weak and also latent (potential ties enabled by ICT) ties (Haythornthwaite, 2002) that provide information and social support in both specialized and broadly-based relationships. Katz and Rice (2002) consider the Internet as having great potential for connectivity without much intention or social cost. Although cyberspace has been viewed as a distinct realm, where social ties do not cross-cut into the physical world (Wellman & Hampton, 1999), Hampton (2003) found that this was rarely true especially in communities where the population is low. He also found that ICT use enabled the growth of weak ties and that online contact could influence the structure of offline interactions. This is particularly useful for occupational groups such as dispersed rural GPs who find maintenance of ties with peers and communities difficult and expensive (Pickering & King, 1995). ICT use hence fosters the connection of ties (Cross & Borgatti, 2004) and contributes to the growth of social capital by supporting many-to-many information exchanges among geographically dispersed people (Quan-Haase & Wellman, 2004).

ICT Use and Performance

Research on ICT use by general practitioners has begun to extend beyond informatics in hospitals and specialty medicine to include computing in general practice settings (Fafchamps, 1991; Aydin & Forsythe, 1997). In some healthcare settings across Australia, the use of ICT systems is relatively new. It is only in the last few years that computerised clinical/critical pathways, computerised medical records, patient acuity/dependency levels, and patient information systems have been implemented in general practices throughout Australia (Western, Dwan et al., 2001; Western, Dwan et al., 2003). ICT use contributes to process of care by providing benefits to GPs such as better storage and retrieval of information, greater efficiency in terms of time and space, more consistent and accurate records, improved drug

management, better legibility and presentation, more flexibility, tighter security, and integration of clinical and administrative functions (Nielsen, 1998). It appears that ICT is utilised, and is a good fit with the general practice tasks it supports (Goodhue & Thompson, 1995). It is hence possible to derive the following hypotheses based on theoretical findings discussed in this section and the previous one:

H4: The use of ICT by a GP for clinical-task based functions is positively associated with performance attitudes

H5: The use of ICT by a GP for Internet-task based functions is positively associated with performance attitudes

H6: ICT use significantly moderates the interaction between network structure and performance attitudes

Performance

Performance, in any research, is a concept that is extremely difficult to capture and measure as it deals with multitude of factors making it difficult to establish internal validity. Performance literature in the context of general practice focuses on clinical appropriateness, standards of medical care, health outcomes and so on. Donabedian's (1980) theoretical framework is widely cited for evaluating performance in terms of 'quality of care'. Quality of care is further classified as structure, process and outcome. Campbell, Roland, and Buetow (2000) extend Donabedian's model by defining quality of care as "whether individuals can access the health structures and processes of care which they need and whether the care received is effective". Table 1 below refers to the dimensions of quality and care.

<i>Care</i>			
	Health Care System (Structure)	Patient-centred Care (Process)	Consequences of Care (Outcomes)
<i>Quality</i>			
Accessibility	<ul style="list-style-type: none"> - Geographic access - Affordability - Availability 	<ul style="list-style-type: none"> - Affordability - Availability 	<ul style="list-style-type: none"> - Health Status - User Evaluation
Effectiveness		<ul style="list-style-type: none"> - Effectiveness of Clinical Care - Effectiveness of Inter-personal Care 	<ul style="list-style-type: none"> - Health Status - User Evaluation

Table 1: Dimensions of Quality of Care (Campbell, Roland et al., 2000)

However, because the scope of the paper is limited to the “provision of primary continuing comprehensive whole patient medical care” (as per the RACGP (2004) definition of general practice in Australia), we regard the ‘*process of care*’ dimension of quality of care between GP and patient as relevant for the study. In particular, we are interested in the *effectiveness* of the GP in delivering clinical and interpersonal care.

To this end, we find that comprehensively measuring the GP’s attitude towards these dimensions of care comes closest to measuring their actual behaviour. Research in social psychology suggests that a person’s attitude towards an object may be related to the overall pattern of a person’s response to that object (Ajzen & Fishbein, 1980). For example, it follows that GPs who strongly believe that behaviours such as smoking should be eliminated because of the risk of health, might be more likely to find out whether their patients smoke, and to offer pamphlets, advice or medication to help them give up (Cockburn, Killer et al., 1987). It is therefore safe to argue that the perceptions the GPs hold are likely to influence their behaviour in the consultation and it is the attitude towards delivering effective quality care or the *perceived effectiveness* that we are interested in. We denote perceived effectiveness as “performance attitudes” in this study.

Method

This section describes the process of designing our instrument for collecting both network and attribute data from the GPs.

Network Data: Collection Approaches & Instrument Items

Two main approaches to network data collection are the whole (or sociocentric) network and the egocentric network approach². Whole network analysis focuses on identifying structural patterns in cases that can be generalised (Wellman, 1926). In this approach, actors of the network are a priori defined. For example, data gathered from an entire group of physicians (which is the interest of study) in a practice is a whole network. The network represents the saturation sample of interest and the analysis allows for the results to be generalised to this population. Therefore, this approach remains the gold standard because of its ability to gather data for the entire network. Data collection using a whole network approach usually involves listing the names of the actors in the form of an adjacency matrix (Scott, 2000). When respondents are administered the network survey consisting of the roster of names, they usually check off the names of people whom they know depending on the name generator question asked. Problems related to identification of every actor in the network and issues of recall thwart the use of whole network approach (Bernard, Killworth et al., 1982). For example, it is not feasible to make a roster of 1,000 GPs and ask each of them to recall their relations with each other.

The egocentric approach may be an alternative to the sociocentric approach because of its practicality and feasibility. In this approach, the actor of interest is referred to as the “ego” and the actors referred to by the “ego” as his affiliate, advisor, friend, or relative, are known as “alters” (Scott, 2000). Name generators are used in order to elicit alters’ names. In our study, we used the following name generator to elicit names from a GP’s professional network:

² For an overview about these approaches in the medical domain see Chung, Hossain et al (2005a).

“By ‘professional network’, we mean professional people whom you associate, interact or work with for the provision of care to patients (eg. nurses, admin staff, specialists, pathologists, doctors etc.) Looking back over the last six months, please identify people (up to 15 maximum) who are important in providing you with information or advice for providing care to patients.”

Name interpreter questions are also commonly asked to elicit some attribute data about the alters and ties. In our case, we requested GPs to also provide their occupational roles and proximity of work with their alters. The justification for including these items originate from literature which suggests that occupational hierarchy of health professionals affects the nature of clinical practice (West, Barron et al., 1999; Chung, Hossain et al., 2005a) and that work proximity affects work performance (Kiesler & Cummings, 2002; Cummings & Cross, 2003; Cummings, 2004). These variables will need to be controlled for during analysis of the interactions between network structure, ICT use and individual performance attitudes. Other name interpreter items solicited were strength of each tie, measured by “time known the person”, “frequency of interaction”, “type of relationship”, and “degree of closeness” (Granovetter, 1973; Marsden & Campbell, 1984; Marsden, 1990). Attribute data about the frequency of interaction via email, telephone (including mobile), and video conferencing were also included in the instrument to segregate face-to-face and ICT media interactions.

A significant question in the egocentric approach concerns asking the ego about the relationship between elicited alters in order to complete the network structure. In our study, we asked GPs to determine how the members of their professional network relate to each other based on a five point degree of closeness scale ranging from ‘especially close’ to ‘do not know each other’. In other words, for each alter nominated, the GP would determine a closeness scale for every other alter. Although this approach has been criticised in the past for its recall reliability and accuracy (Bernard, Killworth et al., 1982; Bernard, Shelley et al., 1982; Bernard, Killworth et al., 1985), later studies confirmed that people also remembered long-term or typical patterns of interaction with other people rather well (Freeman, Romney et

al., 1987; Corman & Bradford, 1993). Furthermore, the free recall method (in egocentric approach) elicits a richer data on the social networks of people whereas the fixed choice method (in sociocentric approach) influences people to elicit accurate information on the most important relationships (ie. strong ties) (Hammer, 1984).

ICT Use Items

ICT use in general practice can be measured using a questionnaire items measuring the level of a GP's current use of ICT in their daily practice, including their knowledge and use of various information resources, both online and print. In our study, ICT includes computers, technological software applications and systems such as Medical Director, PDA (Personal Digital assistants), email, fax, telephone, video conference and so on. Based on Sproull and Kiesler's (Sproull & Kiesler, 1991) categorisation of the effects of ICT use as task-level and communication-structure effects, ICT use in our case was divided into clinical tasks (task-level) and internet tasks (structure effects). Clinical task measures were based on the reliable and valid item sets (Cronbach's alpha coefficient = 0.865; factor loadings were significant – range = 0.802 to 0.528) used by Western et al (2001) and includes items such as frequency of using ICT for “Generating health summaries”, “Writing prescriptions”, “Running a recall system to remind patients for routine tests”, and so on. The items were measured on a five point scale ranging from ‘Daily use’ to ‘Never’.

Clinical Tasks	Factor Loading
Generating health summaries	0.802
Recording progress notes	0.774
Using decision support functions	0.719
Writing prescriptions	0.719
Accessing educational material	0.704
Receiving or storing pathology results electronically	0.665
Preparing referral letters for patients	0.608
Running a recall or reminder system	0.528

**Table 2: Factor Loading for the Clinical Tasks Items
(Western, Dwan et al., 2001)**

Internet task items were adapted from Andrews et al's (2004) and included “accessing medical journals”, “accessing databases”, “finding information to help patients”, “consultation with colleagues”, and so on. These item sets were developed by the University

of Kentucky's Department of Family Practice in a project supported by the Agency for Healthcare Research and Quality (AHRQ) in the US. The same instrument was used in another study by the same authors (Andrew, Pearce et al., 2005).

Attitudes to Process of Care Items

We used Cockburn et al's (1987) validated and reliable item set for assessing GPs' attitudes to quality care. The item set accounts for attitudes of both clinical and interpersonal care through seven dimensions, although only six are relevant for this study. The dimensions are: psychological orientation, preventive medicine, mutuality, communication, responsibility for decisions and appropriateness of consultations. Cockburn et al (1987) performed the principal components analysis with varimax rotation on the 32 items out of which 10 factors were extracted with eigenvalues greater than one. The 10 factors accounted for 57% of the total variance (considered adequate) and were rotated to simple orthogonal structure using varimax orthogonal rotation with Kaiser normalisation. Finally, items with a high factor loading of at least 0.40 on only one factor were grouped together to form an index. Internal consistency for each of the factor-based items were estimated using Cronbach's alpha (table 3).

Factor-based subscale	Alpha
1	0.62*
2	0.67*
3	0.56*
4	0.44
5	0.59*
6	0.60*
7	0.48
8	0.36
9	0.53*
10	0.32

*Above Standard (0.50) which indicates internal consistency

Table 3: Reliability coefficient (Cronbach's alpha) for factor based subscale (Cockburn, Killer et al., 1987)

As we intend to use the alpha coefficients for group comparisons (groups with high performance attitudes versus groups with low performance attitudes for instance), minimum alpha coefficients of 0.50 for the subscales are recommended for this purpose (Nunnally, 1978). Although factor seven fails to indicate internal consistency at 0.48, Cockburn et al

(1987) retained it because the questionnaire was still in its early stages of development. Therefore, in our study, we will be testing its reliability when actual data is collected from the GPs. The item sets are included in the appendix.

Demographic Items

Demographic details were also solicited from GPs. We asked GPs to state the number of years they have been practising as GPs and number of years they have practised in the current practice in order to ascertain their years of experience. This is an important variable as research has shown that age and clinical experience is a covariate of performance. In particular, Choudhry et al's (2005) systematic review of the literature on GP experience and performance show that quality of care delivered declines as GPs age. We also asked for year of graduation, medical college and country from which the GP graduated, gender, number of GPs in the practice, whether they had hospital appointments, and if they were members of the 'Fellowship of the Australian College of Rural and Remote Medicine' (FACRMM) and 'Royal Australian College of General Practitioners' (RACGP). Inclusion of these items sets and others in the instrument were confirmed and validated with GPs from NSW, including those who held senior positions (for instance, president of the Rural Doctor's Network and president of the RACGP) in the field of general practice.

Operational Model

The operationalisation of our concepts in the conceptual framework (figure 1) can be translated into the below diagram based on the review of literature in the above sections. Note that although we hypothesise that there is an association between ICT use and network structure, and ICT use and performance attitudes, only the moderation effect of ICT use on the relationship between network structure and performance attitudes is depicted.

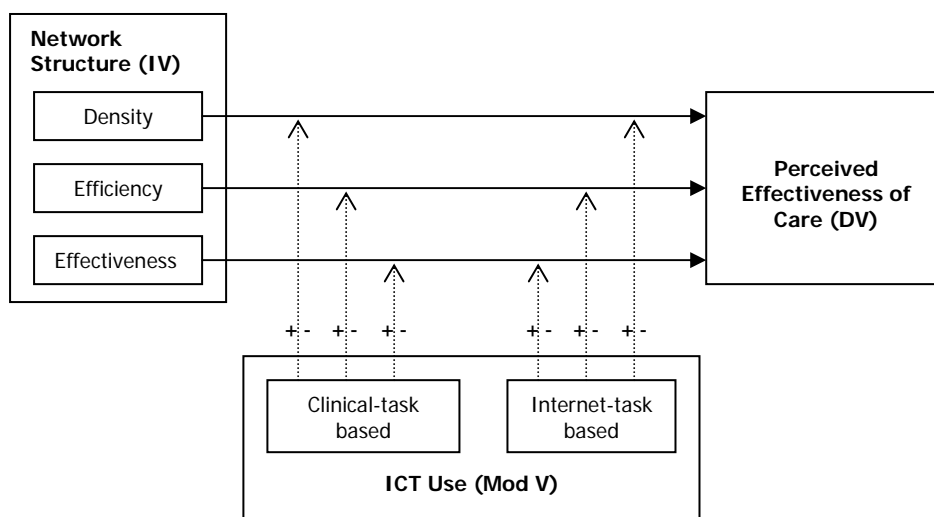


Figure 2: Framework for study showing operationalisation of concepts

Data Storage and Extraction

We utilised mySQL (5.0.24-community-nt) server database for storing survey instrument data. The advantages of designing a database to store data for this study are that it allows for a simulation of data population as well as flexible and efficient retrieval of network and attribute data based on structured query language. It is designed specifically so that data integrity is preserved by ensuring that invalid codes in the survey instrument cannot be entered. Also referential integrity in the database ensures that if, for example, a GP's record is deleted from the database, then all his/her alters' information are also deleted. Furthermore, the results can be exported into a data file (comma separated values) which can then be loaded into SPSS or Excel for further analysis. We utilised Perl (v5.8.8 ActiveState) to populate the database with synthetic data in order to simulate GP responses to obtain preliminary reliability and validity of the instrument. A secondary objective was to 'rehearse' the data analysis procedure prior to obtaining empirical data. Another Perl script was written for extraction of network data from the database and conversion into 'vna' formats for network analysis using the UCINET 6.87 and Netdraw 2.4 program (Borgatti, Everett et al., 2002).

Measures

The following are brief description of the measures utilised in this study.

Network Structure

Density

Network *density* basically represents the actual number of ties in a network as a ratio of the total maximum ties that are possible with all the nodes of the network (Hanneman, 2001). A fully dense network has a network density value of 1, which indicates that all nodes are connected to each other. A network with a density value near 0 indicates that it is a sparsely-knit network. In our simulation program, we accounted for an undirected graph with N nodes and N_t ties to calculate the density (D) as:

$$D = \frac{2 N_t}{N (N - 1)}$$

Efficiency and Effectiveness (Effective size of the network)

The structural holes measure, *effective size*, is a measure of the number of alters (ie. social contacts of a GP) minus the average degree of alters within the ego (GP) network, not counting ties to the ego. It indicates the ego's total impact in the network in terms of overall reach and access to anybody in the network.

Efficiency is measured by dividing the effectiveness by the number of alters (or degree) in the ego's network. It aids in determining the ego's proportion of ties in the network which are non-redundant.

ICT Use

Composite scores for *frequency usage of 'clinical-based tasks'* and *frequency usage of 'internet-based task'* categories of ICT use will be used summated. The scores form an index and allow us to categorise and recode respondents in terms of whether they are high, medium or low ICT users.

Performance Attitudes

Performance attitudes are measures along six of the seven *dimensions* adapted from Cockburn et al's (1987) study. The dimensions were also used successfully in another study to correlate clinical practice organisation and work stress to GPs' attitudes (Howie, Hopton et al., 1992).

In our study, we will form composite scores for each of the dimensions. For example, a high composite score in the psychological orientation would presumably be associated with ‘good’ outcomes in the consultation in terms of accuracy of diagnosis, patient satisfaction and compliance; a high score on the communication dimension shows GPs viewing communication as important are more likely to achieve patient satisfaction, a high score on the appropriateness of consultation dimension may reflect a GP’s satisfaction with their role; and so on.

Simulation for Instrument Data Population

While the realism of populating computer generated data into a social network survey instrument can be disputed and unmatched to real empirical data, we utilised this approach for several reasons as a work in progress and while pilot testing of the survey is ongoing at the time of writing. Firstly, early simulation of data population allows us to test the integral design and robustness of our data collection, extraction and analysis process. Essentially, it allows for us to fine-tune various aspects of the design model at an early stage rather than when realistic data is collected. Secondly, it allows for the research to rehearse and experiment with different sorts of data for the analysis, including outliers and missing values. In the following sections, we describe the design of the data population process.

Data Population Process

The essence of any simulation experiment begins with a random number generator. For our purpose, we utilised the random (`rand()`) function in Perl and modified to suit our purpose such that it would produce a discrete random number between a minimum and a maximum given number. Every entry, except for generation of the GP ID (identity), in the database was populated based on this function. Several rules and constraints were incorporated in the data population program. For example, a GP’s years in general practice has to be greater or equal to his years in current practice; the maximum connections of a GP’s alter network cannot be greater than $n(n-1)/2$ assuming symmetric interaction ties; and so on. The motivation for

the generation of simulated data was based on the work Tsvetovat and Carley (2005). The logic of the data population algorithm is as follows:

```
N=500; // Number of GPs to simulate
Generate GP Profile; // Creates GP & demographic items
FOR each GP until N DO
  Generate GP_ID // Creates GP, GP alters, & alter attributes
  Generate n alters // creates number 'n' no of alters
  FOR each of n alters DO
    Generate gp_network as gp_id, alter_id, alter names,
    work proximity code, occupation code, closeness, frequency,
    time known, and frequencies (of ICT communication)
  END FOR
END FOR

FOR each GP DO
  Get number of alters for each GP
  FOR given alter number of each GP DO
    Generate alter-alter ties & closeness code for each alter
    IF alter already has tie with alter then
      Do not generate tie again
    END IF
    Generate ICT use values
    Generate Attitudes to Process of Care values
  END FOR
END
```

Data Extraction Process

Data extraction was a two phase process. The first phase involved extracting ego network data of the GP and the alters and converting the relational data into an input file (vna format) for analysis in Netdraw. Batch files (equivalent of scripts) were written in the DOS environment for analysing the vna files (500 files from the simulated output of 500 GPs). The batch command is as below:

```

rem Author: Kenneth Chung
rem Date: 22/10/2006
rem Description: This is a batch program that takes each vna filename
rem listed in the current directory as an argument and writes it in as
rem part of the loadvna argument in a file called batch.txt. The
rem batch.txt file is then read by netdraw and an output file is computed.
rem This output filename is described in the batch.txt file. The output
rem filename will be called "em_$inputfile.txt" where $inputfile is
rem the name of the input file. So an input vna file called "gp_1.vna"
rem will have a corresponding output file called "em_gp_1.txt" containing
rem the ego measures (em) for GP1. This file will later on be parsed by
rem Perl to extract the GP_id and the effectiveness and effsize into a
rem file containing the gp_id, density, effsize, effici.

for %%e in (*.vna) do ((echo loadvna %%e
echo runlayout
echo egomeasures
echo outputattr em_%%~ne.txt density degree indegree outdegree effsize
efficiency constraint hierarchy
echo close) > batch.txt
echo @echo off > netdraw.bat
echo "c:\Program Files\Ucinet 6\netdraw.exe" batch batch.txt >>
netdraw.bat
call netdraw.bat
)

```

The second phase of the data extraction process involved querying the database for the attribute data such as ICT use item values and attitudes to process of care item values. The extraction script was programmed in Perl. It also calculated density and collated the results from phase one (ego network values) and phase two (attribute values) into one comma separated values (csv) file for analysis in SPSS. In total, there were 500 records.

Preliminary Data Analyses with Descriptive Statistics

The following tables show the distribution of data for the network variables.

	N	Minimum	Maximum	Mean	Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Statistic
Effective Size	500	1.000	5.000	2.53725	1.095860
Efficiency	500	.143	1.000	.40552	.221740
Network Density	500	.0000	.5000	.356423	.1297960
Valid N (listwise)	500				

	Skewness		Kurtosis	
	Statistic	Std. Error	Statistic	Std. Error
Effective Size	.131	.109	-1.049	.218
Efficiency	1.822	.109	2.330	.218
Network Density	-1.895	.109	2.871	.218
Valid N (listwise)				

Table 4: Descriptive statistics showing distribution of network variables

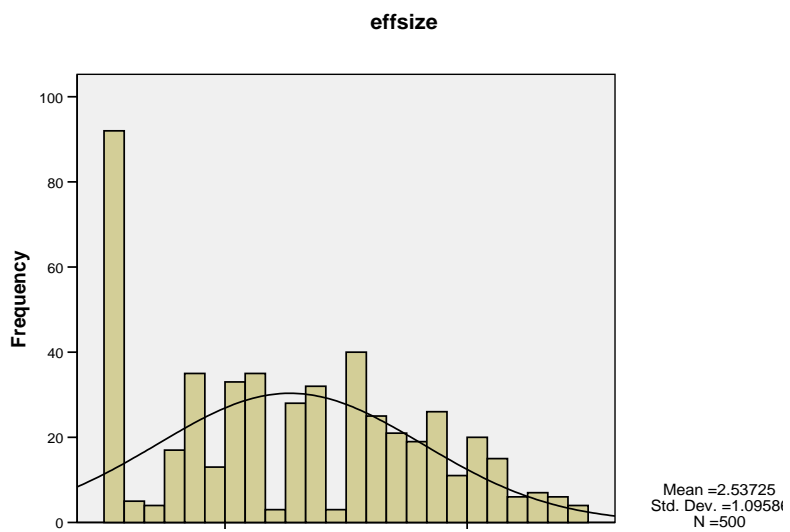
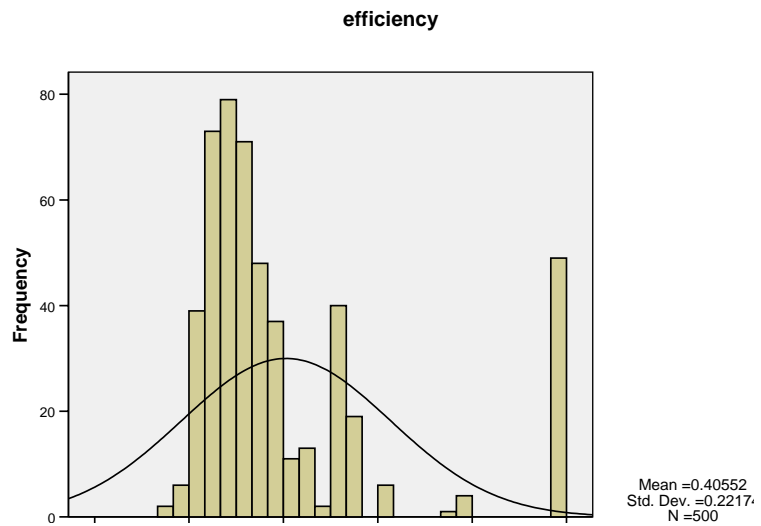
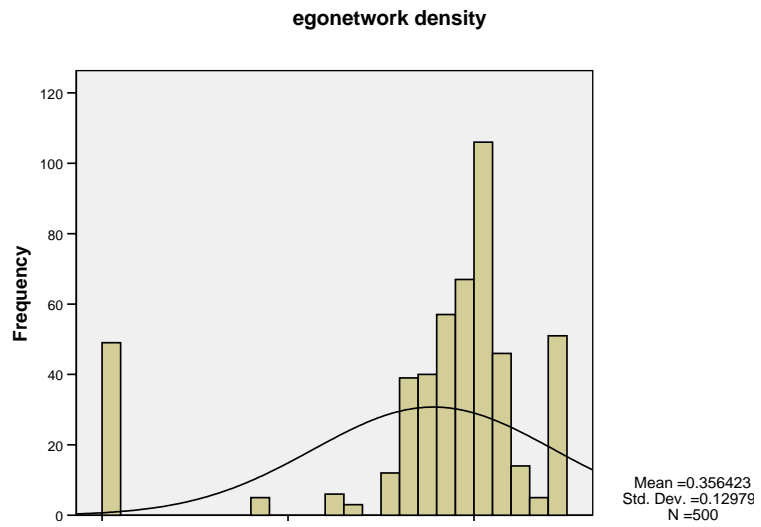


Figure 3: Histogram showing distribution of ego network variables with normal curve

Note that the mean values for the distributions are 0.356, 0.406, and 2.538 for the network density, efficiency and effective size respectively. The Skewness values for the same variables are 0.131, 1.822 and -1.895 which are all within the acceptable range for analysis (Miller & Brown, 1997). However, the Kurtosis values for efficiency and network density are relatively high (2.33 and 2.871) from the normal distribution. This is possibly related to the fact that there are some outliers in the distribution of the data.

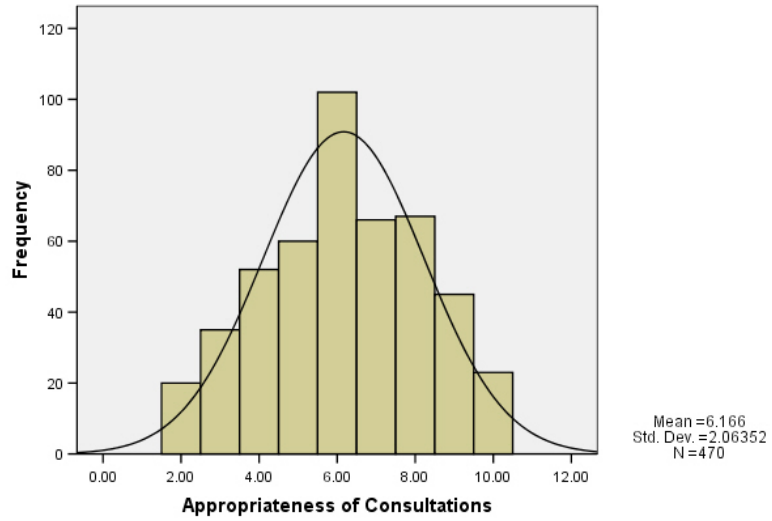
Regarding the attitudes to process of care, we segregate the data into 6 dimensions. The descriptive statistics are outlined below:

	Psychological Orientation	Preventive Medicine	Mutuality	Communication	Responsibility for decisions	Appropriateness of Consultations
N – Valid	454	456	451	460	467	470
– Missing	46	44	49	40	33	30
Mean	8.9581	8.9035	12.1175	8.9326	5.9101	6.1660
Std. Deviation	2.52327	2.50176	2.90776	2.38683	2.02252	2.06352
Variance	6.367	6.259	8.455	5.697	4.091	4.258
Skewness	.032	.141	.051	-.104	.034	-.100
Std. Error of Skewness	.115	.114	.115	.114	.113	.113
Kurtosis	-.517	-.437	-.301	-.303	-.615	-.702
Std. Error of Kurtosis	.229	.228	.229	.227	.225	.225
Minimum	3.00	3.00	4.00	3.00	2.00	2.00
Maximum	15.00	15.00	20.00	15.00	10.00	10.00

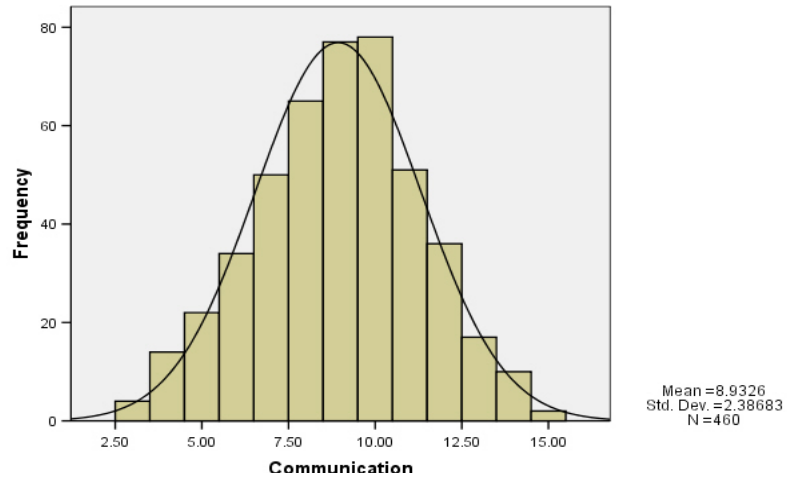
Table 5: Descriptive Statistics for the six dimensions of attitudes of process of care

The simulation results have factored in both missing and invalid codes to reflect what actually will happen during the process of collecting real data. By far, the mutuality dimension has the most missing cases (49). Note that although this is the case, the distribution shows excellent skewness and Kurtosis values, being between +1 and -1. This allows us for psychometric analysis to be performed. The distributions are graphed below.

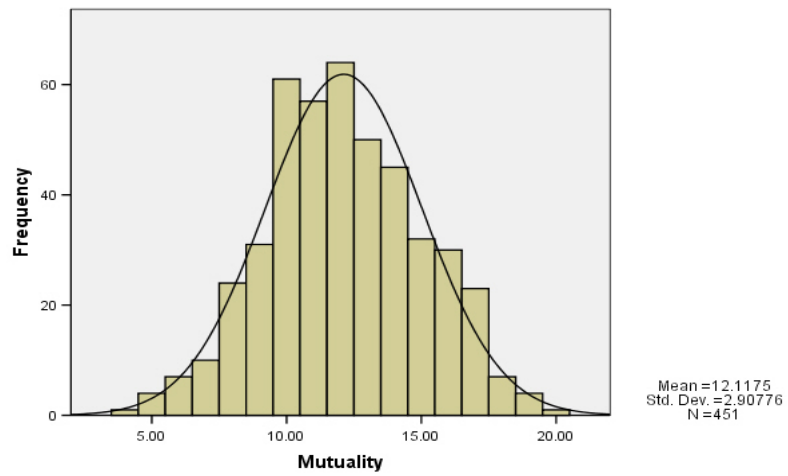
Appropriateness of Consultations



Communication



Mutuality



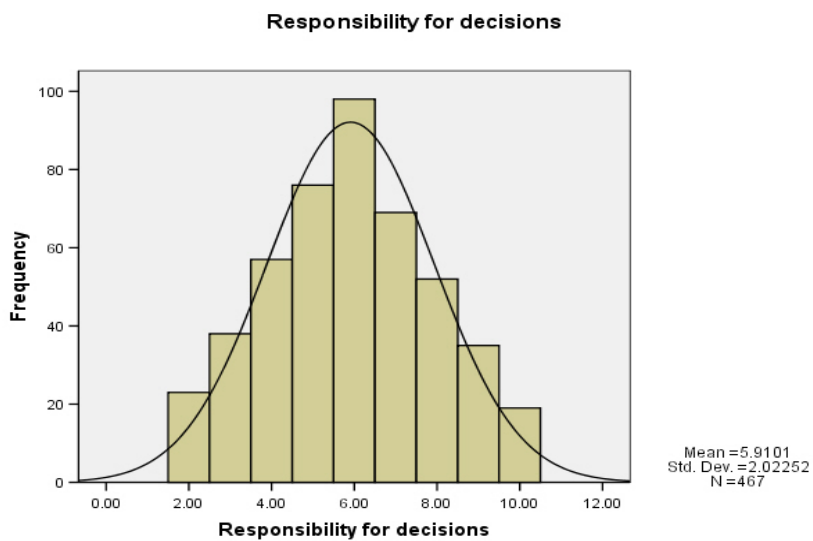
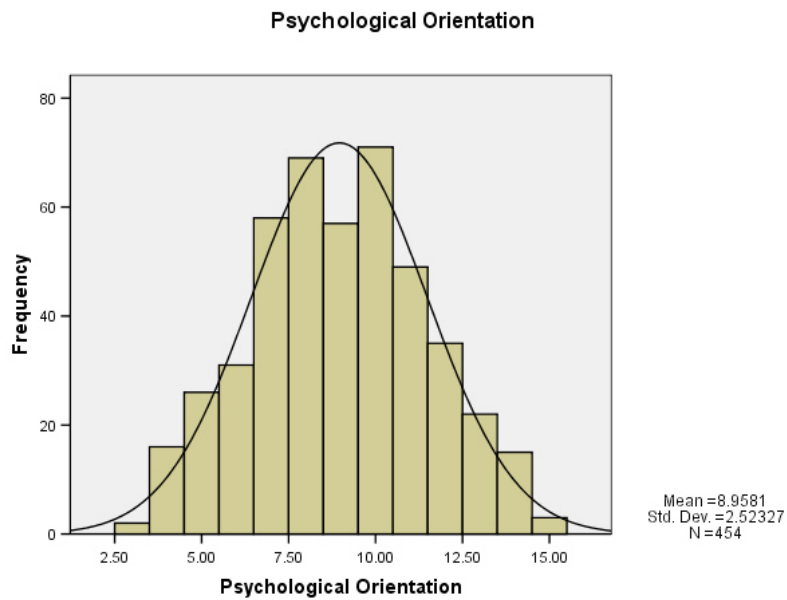
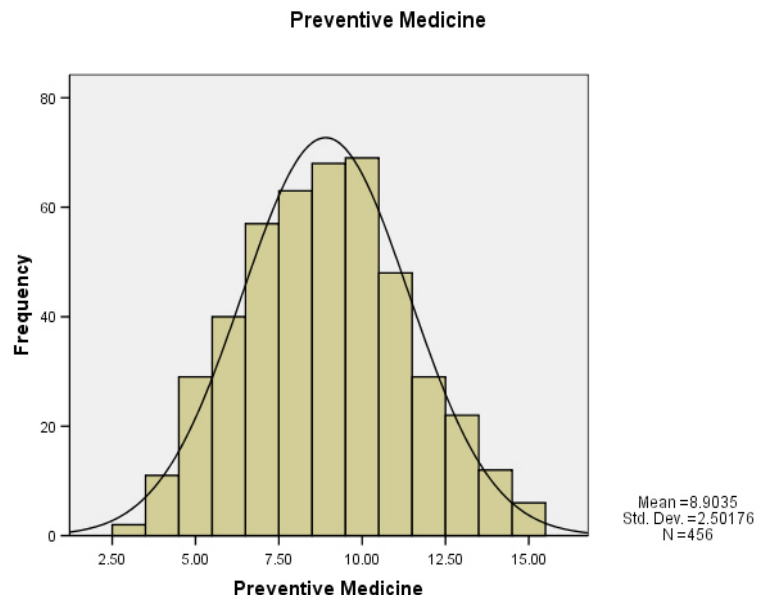


Figure 4: Histogram showing distribution of Attitudes of Process of Care with normal curve

The ICT use data was categorised into ‘Clinical based’ tasks and ‘Internet based’ tasks. From the descriptive statistics below, both categories show excellent skewness and Kurtosis values (between the range +0.1 and -0.1) allowing us for further analysis.

		Clinical Functions	Internet Functions
N	Valid	399	398
	Missing	101	102
Mean		24.1353	39.1633
Std. Deviation		3.90486	4.15093
Variance		15.248	17.230
Skewness		.101	-.063
Std. Error of Skewness		.122	.122
Kurtosis		-.203	-.252
Std. Error of Kurtosis		.244	.244
Minimum		14.00	27.00
Maximum		34.00	52.00

Table 6: Descriptive statistics of ICT use

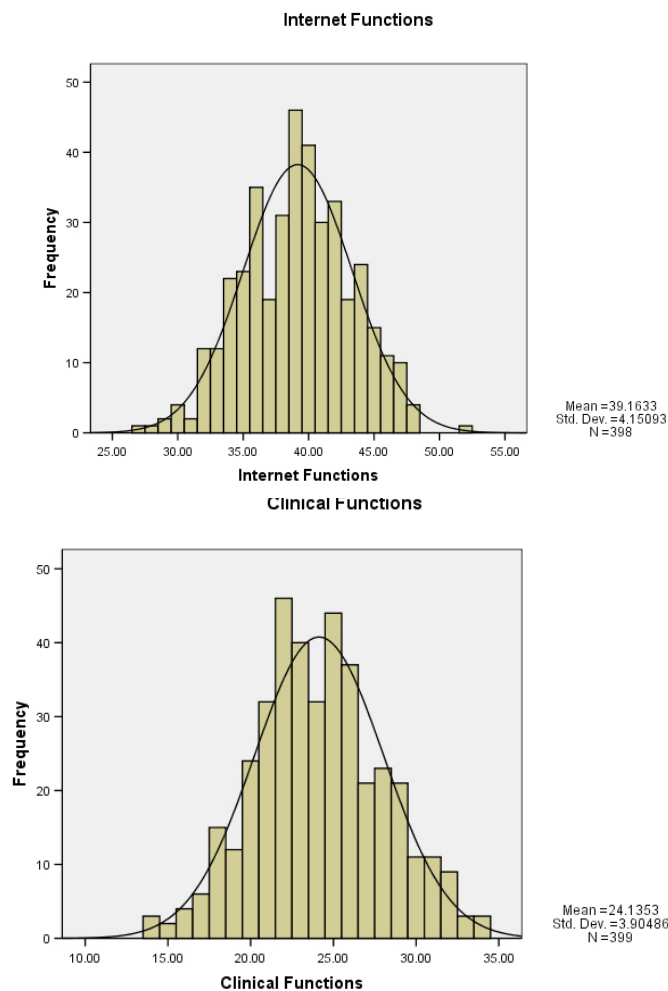


Figure 5: Histograms showing ICT use distribution of Internet Functions with normal curve

Conclusion

This paper begins by introducing a conceptual model to explore the effect of social network structure and ICT use on the performance of individuals involved in knowledge intensive work. The domain for the study is the general practitioners in rural NSW, Australia. This study hypothesise that by studying the interaction effects between an individual's network structure and ICT use, one can better understand its implication on individual performance. To this end, we demonstrate how the conceptual model can be operationalised by developing a reliable and valid survey instrument based on past research. We demonstrate the approaches to data collection, and in particular, how we utilised the egocentric network approach. We also provide directions for network and attribute data storage, extraction and analysis. Finally, we used a simulation based approach to populate the data and show some preliminary data analysis using SPSS. The main advantage of using a simulation approach at this stage of the research is the ability to test the integral design and robustness of the data collection, extraction and analysis procedures. It also allowed for testing of experiments with different kinds of data for the analysis including outliers and missing data.

Appendix

Attitudes to Process of Care Questionnaire

1. I feel that it is a waste of time trying to persuade patients to give up smoking.
2. I believe that I should always inform patients about their prescribed treatment, making sure they understand my expectations.
3. An important part of my role is simply to listen to patients' worries.
4. Counselling patients with personal problems can help them to cope better in the future.
5. My medical expertise is often wasted because I see so many people who are not sick.
6. Identification of modifiable risk factors such as smoking is a very important aspect of my work.
7. Often patients make a convenience of me by bringing problems which they should solve themselves or take elsewhere.
8. I believe that effective medical treatment depends on a partnership in which the patient plays an active part.
9. Providing emotional support for patients is important for my personal satisfaction.
10. It is important for me to be frank and open with patients.
11. I believe that GPs are very influential in persuading patients to change their lifestyles.
12. I think that it is my job to treat physical disease and leave tasks such as counselling to their professions.
13. Patients are more likely to follow my advice concerning their physical complaints than advice concerning their social or emotional problems.
14. The majority of patients do not wish to be involved in the decision making about their treatment.
15. The more information I give patients about their diagnosis and treatment, the more likely they are to comply with instructions.
16. I usually don't attempt to help patients with psychological problems because they are the result of life situations over which I have little or no control.
17. Most patients would prefer the doctor to take responsibility for their medical problems.

Scoring Key:

<i>Subscale</i>	<i>Items</i>
Psychological Orientation	12, 13, 16
Preventive Medicine	1, 6*, 11*
Mutuality	8*, 9*, 10*, 15*
Communication	2*, 3*, 4*
Responsibility for Decisions	14, 17
Appropriateness of Consultation	5, 7

* *Items scored in reverse.*

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