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Rating accessibility of packaging: a medical packaging example

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Abstract

Few previous work has been undertaken in understanding issues surrounding dexterity and access to packaging. Researchers had access to users who had known dexterity issues and had been advised by their doctor to decant their medication into bottles rather than use unit-dose blister packaging. Hence, it was decided to use a range of techniques to understand this problem. It was further proposed to develop a methodology by which the relative performance of packaging could be assessed with respect to dexterity issues. In this study, there were three objectives to carry out: motion-capture analysis, grip analysis and dexterity analysis when opening the blister packs. Motion capture was carried out on eight people aged 55 years and older, a classification of the grips used when opening blister packs was performed on 57 people aged 18 years and older, and a Purdue Pegboard test was administered to 54 people aged 18 years and older. It was found out that there were four common types of grips used, out of which two of the grips were used by more than 88% of participants. With the motion capture, it was found that each grip and their various associated techniques were compared with each other. Grip 2 utilized the least finger movement. Using the dexterity test results, it was corroborated that dexterity decreases with age, and an accessibility score was developed that can be used by pack designers and manufacturers to assess pack performance. Future work is proposed to develop this methodology further.

Keywords

Blister packaging, inclusive design, dexterity

Disciplines

Medicine and Health Sciences | Social and Behavioral Sciences

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Rating accessibility of packaging: A medical packaging example

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Abstract

In the development of Child Resistant (CR) packaging there is currently a lack of in depth studies performed on blister packaging. In order to aid the development of CR blister packaging that is both effective and meets the requirements of all users, it is essential to understand how users currently use blister packaging. In this study, there were three objectives to carry out motion capture analysis; grip analysis and dexterity analysis when opening the blister packs. Motion capture was carried out on 8 people aged 55 years and older, a classification of the grips used when opening blister packs was performed on 57 people aged 18 years and older and a Purdue Pegboard test was administered to 54 people aged 18 years and older.

It was found out that there were 4 common types of grips used; out of which 2 of the grips were used by more than 88% of participants. This is valuable information that can be used by packaging designers. With the motion capture it found that each Grip and their various associated techniques were compared against each other. Grip 2 utilised the least finger movement. Using the dexterity test results, it was corroborated that dexterity decreases with age and an accessibility score was developed that can be used to determine the dexterous ability of a person to open blister packaging.

Introduction

Issues relating to strength and dexterity become ever more important as the average population age in developed nations increases. Reduction in strength and dexterity can causes problems in undertaking many aspects of daily living, such as bathing, cooking or using a mobile phone or ATM to name just a few examples. One area of recent interest for research has been the ability of older people to access packaged household goods, food and medicines. Studies have shown that many elderly people experience such difficulties in opening packaging that they will abandon products altogether [1], leading to non-compliance in the case of medical packaging [2], and possibly even malnutrition in the most vulnerable individuals.

There have been numerous previous studies examining the openability of packaging across various disciplines, from the study by Rholes, Moldurp and Laviana [3], The Department of Trade and Industry [4], Voorbij and Steenbekkers [5], Yoxall et al [6] and more recently by Yoxall and Janson [7], Su et al [8], Kuo et al [9], Chihara and Yamazaki [10], Silva et al [11] and Bix [12]. The vast majority of packaging related work has looked at issues related to the strength of consumers particularly opening jars. This type of packaging is commonly used for sauces, preserves and pickles and the McConnell survey outlined earlier [1] ranked jars after bleach bottles as the second most difficult item to open.

Whilst understanding the force required to open a jar is important given their problematic nature (as discussed above), work by Bell et al [13]showed that a significant number of packaging items that users struggled to open were problematic due to issues of dexterity rather than strength with users describing shrink wrapped biscuits, milk and cartons as 'fiddly'. The McConnell survey discussed previously also identified several items that could be considered 'fiddly' such as shrink wrapped cheese, cellophane on ready-meals, biscuits, milk cartons and soap boxes (Figure1). Amore recent study by Payne [14] listed envelopes and packets along with similar items to the McConnell study. Clearly understanding dexterity and pack use and developing a methodology to assess packaging in terms of dexterity is a useful tool for designers, manufacturers and researchers.

In an attempt to understand this issue in more detail it was proposed to study users accessing a pack that was considered 'fiddly' and to examine it in detail to aid in the development of this methodology. In was decided to look initially at non-child resistant blister packs since work by the authors had indentified access to medicines as a significant problem for users with known poor (measured) dexterity. These users had been advised by their doctors to have their prescription medicines decanted into bottles without Child Resistant Closures due to inability to use Child Resistant Closures on bottles.

Child Resistant Closures (CRC's) are applied to packaging in order to prevent young children from gaining access to harmful contents, most commonly seen in the storage of medicines which when ingested by a child can be extremely dangerous and cause poisoning. And example of a CRC is shown in Figure 2.

More recently there has been a move away from the supply of medication in bottles to 'unit-dose' packaging typified as a PVC form with an aluminium or paper liner as shown in Figure 3. The users described above also had difficulty in obtaining medication from this type of packaging commonly termed a 'blister-pack'.

Work by de la Fuente and Bix [15] tested six different CR and non-CR pack designs, these packs were tested on three different groups:

- people with disabilities
- older adults
- children

The work has been developed as the authors believe that current testing protocols are flawed [16] and an understanding of user's abilities will allow the development of improved CR designs, improving compliance whilst reducing accidental poisoning.

The researchers undertook a series of tests including strength, dexterity and anthropometric measurements. They concluded that to include people with disabilities, a CR pack design should not rely on the use of pinch strength. Further, the study suggested that when finger strength and dexterity are required, user ratings for that particular pack design tend to be low.

Given that it had a known pack format where difficulty of use was clearly linked to dexterity and the authors had access to users with known poor dexterity that normally excluded them from using it was decided to use a non-cr blister pack as a case study for the development of a methodology for understanding pack access and dexterity across various pack forms including CR packaging, household and food items.

Methodology

Therefore in order to develop a more detailed understanding, several experimental methods were used to assess the ease of access of this form of packaging. These were:

- grip analysis
- dexterity analysis
- motion capture analysis

In this study, all 57 participants undertook the Classification Analysis and 54 participated in the Dexterity Test (three participants declined). An older cohort of 8 participants took part in the Motion Capture (4 female, 4 male), the youngest being 56 year and the oldest 83 years (mean age 67). The group of 57 participants had approximately the same number of male to female participants (28 female, 29 male) and covered a spectrum of age groups; with the youngest participant aged 21 years while the oldest was 91 years old (mean age 45 years). Two forms of non-CR blister pack were used in the experiments, one with a round tablet shape and the other with a capsule shaped tablet (as shown in Figure 4a and 4b). Both packs were rectangular in shape of 62mm by 57mm for the oval tablet (pack shown in Figure 4a) and 70mm by 45mm for the round tablet (pack shown in Figure 4b).

Classification Analysis

Previous work by the authors had developed a classification for the types of grips used in accessing food packaging [17]. This classification became useful in identifying how people use and manipulate packaging and which grip types they prefer [18]. An attempt to categorise opening techniques of blister packaging does not appear to have been previously undertaken.

Methodology

As with the earlier references, participant's hands were measured, the measurements included hand length (a), hand width (b) and individual finger lengths (c) as shown in Figure 5. They were then asked to open a pack and their opening technique photographed. Two different pack types were studied one with a rounded tablet and the other with a capsule format.

During the testing, participants were first informed that they would be asked to remove a tablet from each blister pack, then they were asked to give verbal consent to allow the recording of their hands as they carried out the motion. When asked to open the blister pack, participants were asked to open the blister pack as they usually would. They were not told that they would be timed, to ensure that they would perform the motion as they usually did.

Dexterity Test

Purdue Pegboard Tests have been a standard method for measuring dexterity for over 70 years. The Purdue Pegboard Test is a test kit invented by Joseph Tiffin, Ph.D. from Purdue University [19]. The test was originally designed to select applicants for labouring work.

The Purdue Pegboard tests two types of dexterity; macro- and micro- dexterity. Macro-dexterity is defined here as the overall movement of the entire arm(s); that is the ability to move the fingers, wrists, hands and elbows. Micro-dexterity in this context refers to fine-finger movements; that is the ability to perform complex motions primarily with the fingertips.

The Purdue Pegboard test claims its can be used for numerous other purposes; while the more well known experiments have tested for the presence and/or extent of brain damage, learning disabilities and dyslexia [19].

Test Methodology

The tests were carried out according to Tiffin's methodology for the Purdue Pegboard Tests [19]. As part of the test, as a means of identifying the Dominant Hand of the participant, they were asked if they were either right-handed or left-handed, and then they were asked which hand they write with. The first question was to determine what hand they perceived was dominant, while the second question was used to determine which hand performs an obvious high-dexterity skill such as writing [19]. This was due to the fact that a large number of left-handed participants had been taught and brought up to write with their right hands.

Motion Capture

Optical motion capture systems have previously been used by to understand packaging access [13] of vacuum lug jars used for sauces and pickles. To better understand if and why people may have trouble complying with their blister packaged medication, it was decided that an optical motion capture investigation would be the best way of determining such a problem.

Motion capture was undertaken using a Hawk Digital RealTime System that consisted of seven Hawk Digital Cameras connected (one is shown in Figure 6) to a computer running Eva Real-Time software. The Hawk Cameras are specifically programmed to record only infrared light and are mounted with an array of infrared Light-Emitting Diodes (LEDs); whose intensity can be controlled. The cameras are all connected to a computer, running EvaRT 5.0.4, which allows the computer to store and process all the captured data to give a precise and accurate positioning of the object of focus and allows the user to view the object from any angle (point of view).

As the cameras only register infrared light, reflective markers are used to capture the motion of the participants' hands. Markers were placed on participants hands as shown in Figure 5, due to limited time available and the complex nature of analysing the results, this investigation was only open to people aged 55 years and older, as the main aim to see if any difficulties faced when opening blister packs could be examined in detail.

Before any tests could be carried out, the equipment had to be calibrated to ensure correct reading and relaying of data from the cameras to the computer. Calibration had to be performed on both the hardware and software. For the hardware calibration, the cameras are prepared and positioned to focus at a specific point in the test area. The position of each of the cameras relative to the area of interest is measured and entered into the program to help the computer stitch together all the two dimensional movements recorded by each camera to create a three dimensional representation of the movements recorded.

The cameras are able to operate in a range of 1 – 200 fps. It was decided due to the nature of the project and after consulting with experienced users of the software that a frame rate of 120 fps would be suitable to give a detailed enough motion capture without requiring too much time to post-process the data.

To ensure that the software was working correctly, several trials were conducted using three voluntary participants. The participants were seated a table in the centre of the workspace for the investigation. Reflective markers were placed on all the joints of all the fingers and two additional markers on the centre of either wrist. The pack was placed on the table prior to starting the test with the long edge facing the participant (as shown in Figure 7). A pack under test is shown in Figure 8.

Results

Grip types and classification

When analysing the footage it was noticed that each of the participants mainly used one hand to perform the actions required to remove the tablet from the blister pack, therefore this hand was labelled the active hand. The other hand merely aided the active hand by supporting the blister pack or catching the tablet as it fell, therefore this hand was titled passive hand.

Even though the methods (or techniques) associated with each of the grips have been outlined below, the key information was the positioning of the hands at the beginning of the initial motion. There were four grips that were recognised during the categorisation investigation. They are outlined below as follows.

Grip One (The Hold and Push)

This grip involves using the thumb of the active hand to push the tablet out of the blister, while the passive hand is used to grip the packaging (See Figure 9a). Once the blister is broken, the tablet is usually taken out using the other fingers of the active hand. In some cases, once the blister is popped, the pack is flipped over to provide easier access to the tablet and to prevent it falling out. Positioning of the thumb varies, with some participants applying force to the edge of the blister, while others press down on the centre of the blister.

Grip Two (The Hold and Pierce)

In this grip, one hand is used to grip the blister pack while the thumb of the active hand is used to score a cut into the foil (see Figure9b). After the foil is pierced, either the passive or active hand is used to push the tablet out from the packaging. A sharp fingernail is not required to break through the foil, just an adequate amount of pressure. A number of participants mentioned that the method is easier to perform on blister packs that have a stiff backing material. This grip is very similar to Technique One. The hands are positioned in an almost identical way, but with the blister pack held in a flipped (reverse) manner.

The tablet is generally levered out the blister pack by using a twisting motion of both wrists. Some participants used

Grip Three (The Reverse Hold and Push)

This grip is very similar to Technique One. The hands are positioned in an almost identical way, but with the blister pack held in a flipped (reverse) manner (see Figure 9c)

The tablet is generally levered out the blister pack by using a twisting motion of both wrists. Some participants used the same technique, but with a sharp twist of just the active hand to pierce the foil.

Grip Four (The Single Hand Push)

This grip uses one hand to hold and open the packaging, while the other hand is held below the blister pack to catch the tablet once it falls out of the pack (see Figure 9d).

The active hand uses the thumb to push the tablet out of the blister while the index and middle finger provide support; one finger on either side of the thumb.

As can be seen from Figure10, the most popular grips used were Grips 1 and 3. The use of Grips 1 and 3 was spread across all the age groups. While the techniques associated with both grips were similar, those that used the technique linked with Grip 3 were generally faster, as they were not as worried about dropping the tablet with their method.

Grip 2 was generally used by the older participants; the youngest being 30 years old. The technique related to the grip seemed to require the least effort, but generally took a longer time to perform than those using Grips 1 and 3. Speaking to one of the participants who had developed severe arthritis, she said she developed this method herself, as it made the process of removing tablets much easier.

Only two participants demonstrated Grip 4, both of whom were in the 18 to 25 years old age group. But as both participants struggled slightly to perform the technique associated with the grip, it is clear why very few of the participants utilize such a method.

Dexterity Analysis

From the dexterity data and hand measurements collected during this investigation the following graphs were produced.

As can be seen from Figure 11, there is a clear decline in the general level of dexterity between the young and old participants. This decline with age is seen to be far more rapid in the case of micro-dexterity than is seen with macro-dexterity.

Analysis of Results

The trend seen in Figure 11 is to be expected as when one gets older, motor control function of the hands begins to drop and physical conditions such as arthritis tend to start manifesting themselves [20].

While all the dexterity data collected is useful; as it was verified that age has a big effect on the ability to perform fine finger movements, it was still unclear how that could be linked to the ability of the participant to remove a tablet from the blister packs. Out of all 57 participants involved in the study, only 2 people (Participants 40 and 54) mentioned and demonstrated difficulty when opening the blister packs and performing the dexterity tests (indeed, work by Bix [15] also showed that participants that would normally be excluded from pack testing protocols could successfully open screening CR and non-CR packages).

Figures 12 and 13 show macro & micro dexterity verses time for all participants opening both forms of blister pack. These graphs show several things; firstly there is little difference between the shape of the capsule and ability to access. Secondly packaging of this type is affected by dexterity, this is shown by the fact that the gradients of these graphs are negative as shown in Tables 1&2. Packaging that is unaffected by a person's dexterity would be expected to show a gradient close to zero.

Although the gradients seem to suggest a mild relationship between dexterity and openability, the gradients seen in these graphs (Figures 12&13) show a variability of 2seconds with an overall average being 4.0seconds to open the package. Indicating that this gradient is significant within the overall experimental results for the participants.

What is unknown is the significance of population size on this result, from Figure 12 there is an obvious outlier, participant 40 experiences difficulty opening packaging of this type and has their medication decanted into non-chid resistant packaging at the pharmacy. However their dexterity level is within the norms set by Desrosiers [21] and as such should be counted within any population study. Whilst this sample size is not large compared to the overall population, the study was intending to develop a methodology for the assessment of packaging with respect to dexterity. The researchers understand that more work needs to be done to comprehend the affects of sample size on the results.

Motion Capture Analysis

The following charts are displacement – time graphs generated with the data collected from the motion capture investigation. Each of the lines represents one of the markers as shown in Figure 7. The finger displacement using Grip types described earlier is shown in Figures 14-16.

The results show significant differences in finger movement between the different styles. The graph for Grip style 3, Figure 16, clearly shows the way in which the tablet is extracted through the bending of the blister. Of interest is how little relative movement there is between fingers, in contrast to Figure 14 showing the opening using Grip type 1. Here, whilst the motion of the fingers is similar the difference is relative motion is more pronounced. Motion capture analysis for Grip style 2 shows significant differences in finger motion when compared to the other grip styles.

Discussion

A consumer's ability to access packaging is influenced by either a users strength, dexterity, cognition or a combination of these factors. Work has been ongoing in understanding these issues for food packaging by a number of researchers however the majority of this packaging related work to date has been undertaken looking at issues related to strength.

Work by Bell et al [13] showed that a significant number of packaging items that users struggled to open were problematic due to issues of dexterity rather than strength with users describing shrink wrapped biscuits, milk and cartons as 'fiddly'.

A known item of 'fiddly' packaging was identified (a non-cr blister) with a 'known' user who was excluded from using this item. It was then decided to use this pack item to understand issues surrounding packaging dexterity issues and develop a methodology that could be used to assess pack performance with respect to those dexterity issues.

To that end three methods were chosen to study this issue, grip classification, motion capture and dexterity analysis. Grip classification identified 4 grip styles used to open packaging with the majority using one of two type grip styles. It was seen however that older users modified their technique to access the packs using a technique that they believed required less dexterity.

Motion capture analysis was undertaken to understand the finger and hand movements when undertaking the task. This identified that whilst the fingers in Grip style 2 moved independently from each other when compared to other grip styles the maximum variation in finger movement was less indicating an efficient opening method.

Whilst the motion capture identified the grip methods well (the bending style of Grip types 1 and 3) are clearly shown in Figures 11 and 13, post processing the results was extremely time consuming since conflicting markers had to be identified and labelled correctly during each analysis. This would indicate that this method is worthwhile if measured detail is needed but in many cases video recording may suffice.

Lastly, dexterity analysis was undertaken using a Perdue pegboard test. All the users measured were within normal measured variations. Interestingly, even though users were tested that had low dexterity and had been recommended not to use certain types of packaging, were actually able to open the packaging tested. This indicates that the issue of 'fiddly' packaging is likely to be one of frustration whereby the task becomes more difficult than the perceived benefit of access.

In plotting time versus dexterity we can produce a graph the enables a comparative assessment of one pack against another (in this case two very similar blister packs). The slope of the graph indicates the effect of dexterity on pack performance. A horizontal line would indicate a pack whereby access is unaffected by dexterity. Unlike motion capture, Perdue pegboards are quick to use, portable and cheap.

The development of a truly effective CR and non-Cr medical packaging is a complex problem. However a methodology is proposed that will at least provide new designs with a benchmark to assess their effectiveness. It is further proposed that this methodology could be expanded to assess pack formats and provide an effective way to provide a performance comparison.

Conclusions

In this study, the authors used experimental techniques and informal interviews to assess dexterity, hand anthropometrics and cognition. There were several key points to note:

- all users including those with very poor dexterity could actually access the packs. However for some users the time taken was considered so prohibitive that there GP prescribed their medication be delivered in non-CR packaging.
- by combining this time limit with a dexterity analysis we were able to develop an accessibility score. This score could be used to aid the development of CR blister packaging and could be useful as a design guide for other types of packaging.
- packaging dexterity and ability to access the contents did not seem to be related to hand size. This suggests that for blister packaging hand anthropometrics may not be the most straightforward solution to developing CR blisters.
- none of the participants tested, read the instructions printed on the foil side of pack prior to opening. This instruction was similar to Grip style 2.
- users demonstrated four distinct grip styles with two styles dominating. The lesser used styles (termed Grip Style 2 and 4 in this analysis) were user developments after struggling to access packaging. Of interest was that from motion capture analysis Grip Style 2 requires significant finger movement.

Future Work

The methodology developed whereby the time taken to open a pack is plotted against a person's dexterity score and repeated for a number of participants and a line fitted to produce a gradient could be an effective way of establishing the dexterity effects

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to open in the past ten years

What's the worst thing to open?

You said:

1 Tops of bleach bottles
2 Jars
3 Shrink-wrapped cheese and ham and sealed sandwich packets
4 Ring-pull cans
5 Tins of meat/fish
6 Milk cartons and juice cartons (including milk and cream pots for coffee)
7 Child-proof tops on medicines
8 The Cellophane on microwave ready-meals
9 Soap powder boxes
10 Biscuits

16

Figure 1: Results from McConnell survey (2004)

Figure 2: Typical CRC closure

Figure 3: Typical Blister Pack for medicines

Figure 4a: Blister Pack Used in experiment

Figure 4b: Blister Pack Used in experiment

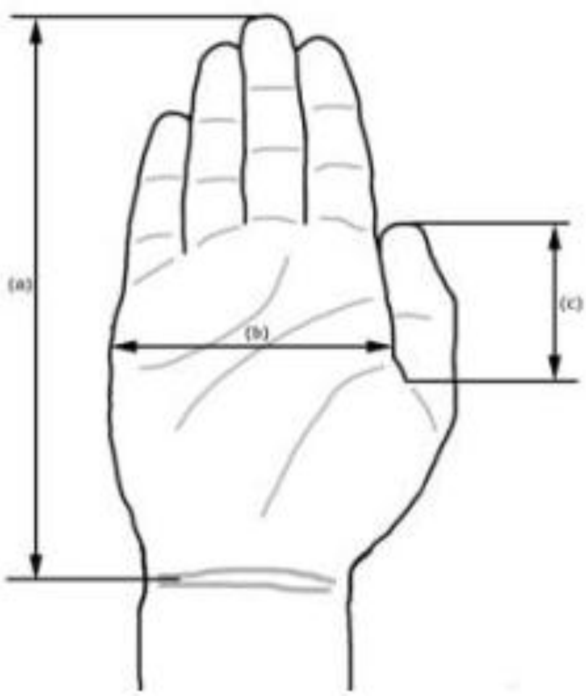


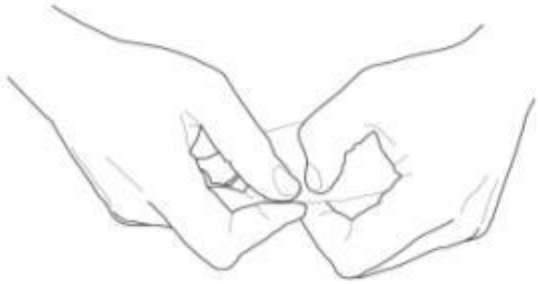
Figure 5: Dimensions measured on the hand (a) length, (b) hand width and (c) individual finger lengths

Figure 6: Motion capture system set-up

Figure 7: Motion capture reflective marker placement on participant's hands and starting position

Figure 8: Motion capture reflective marker placement on participant's hands under test

(a) Method 1 - The Hold and Push



(b) Method 2 - The Hold and Pierce

(c) Method 3 - The Reverse Hold and Push

(d) Method 4 - The Single Hand Push

Figure 6: Blister Pack Grip classification

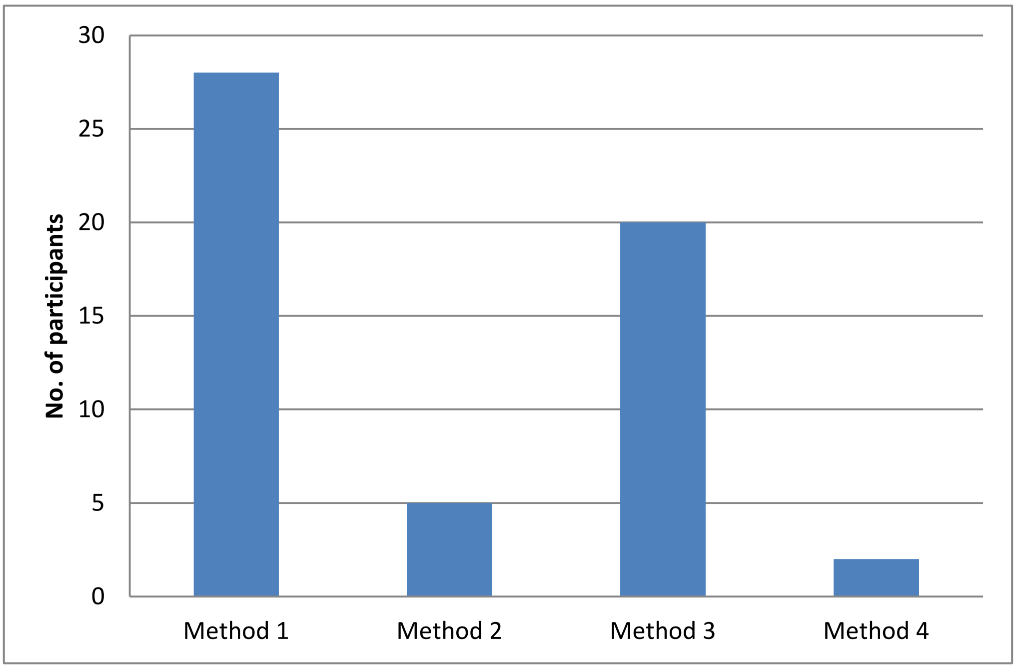


Figure 7: A graph to show the chosen opening method for participants

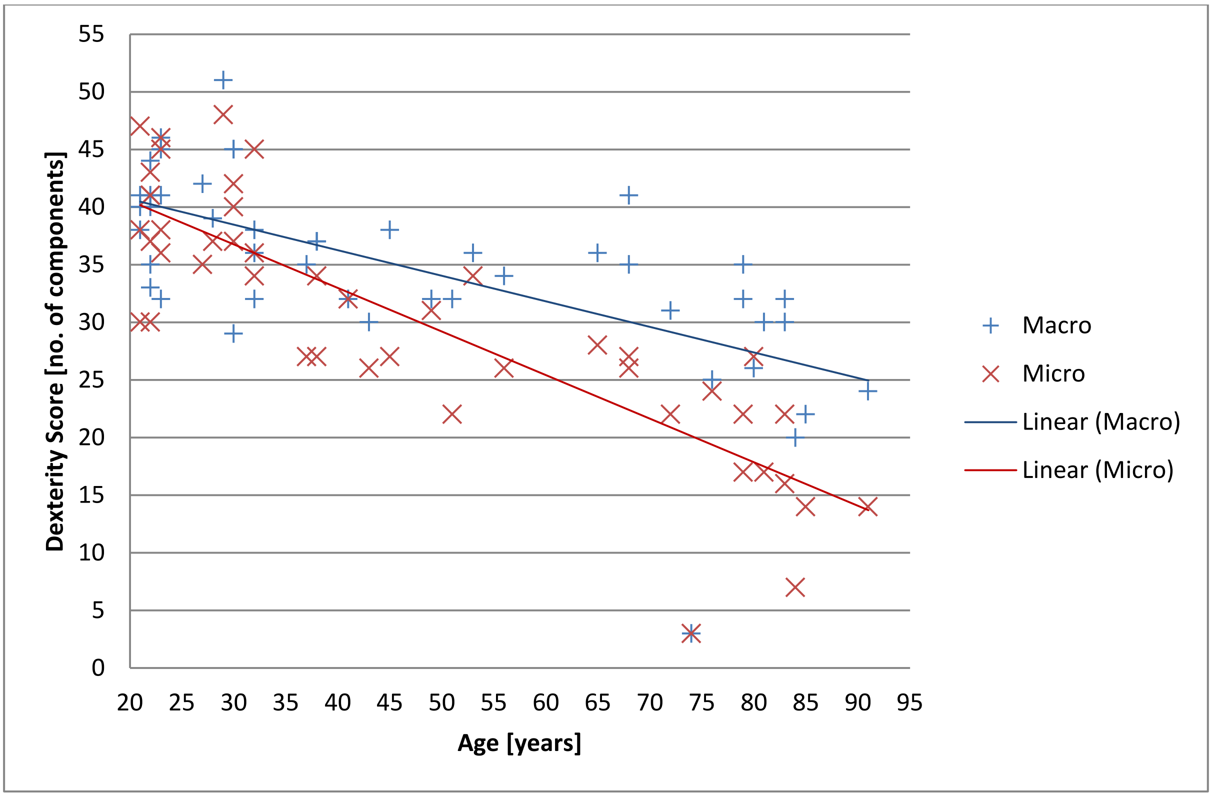


Figure 8: A graph to show the relationship between age and dexterity

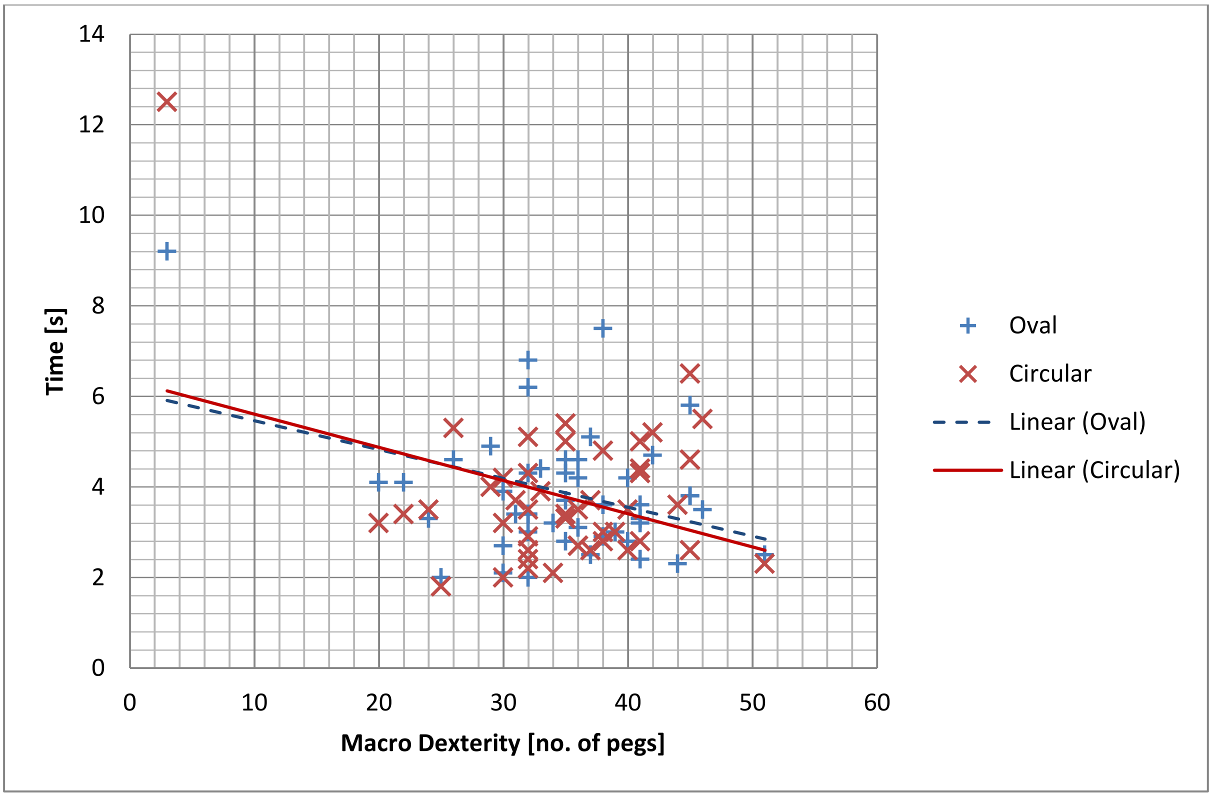


Figure 9: A Graph to Show Packaging Opening Time against Macro Dexterity

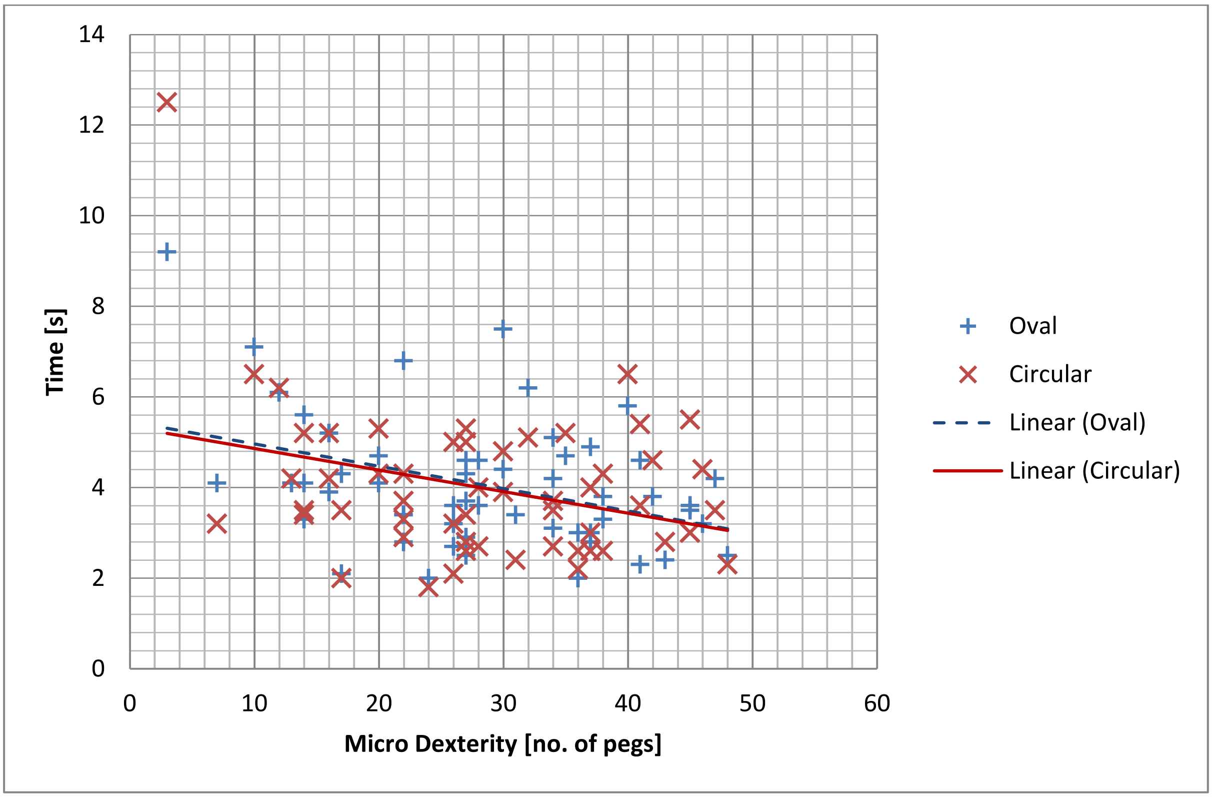


Figure 10: A Graph to Show Packaging Opening Time against Micro Dexterity

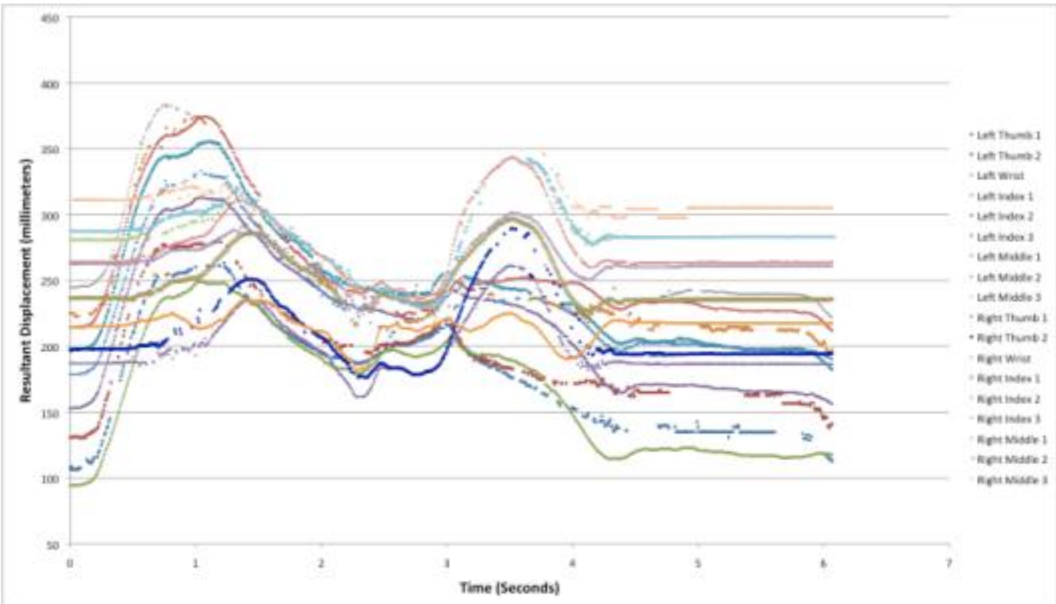


Figure 11: Motion capture results for Grip type 1

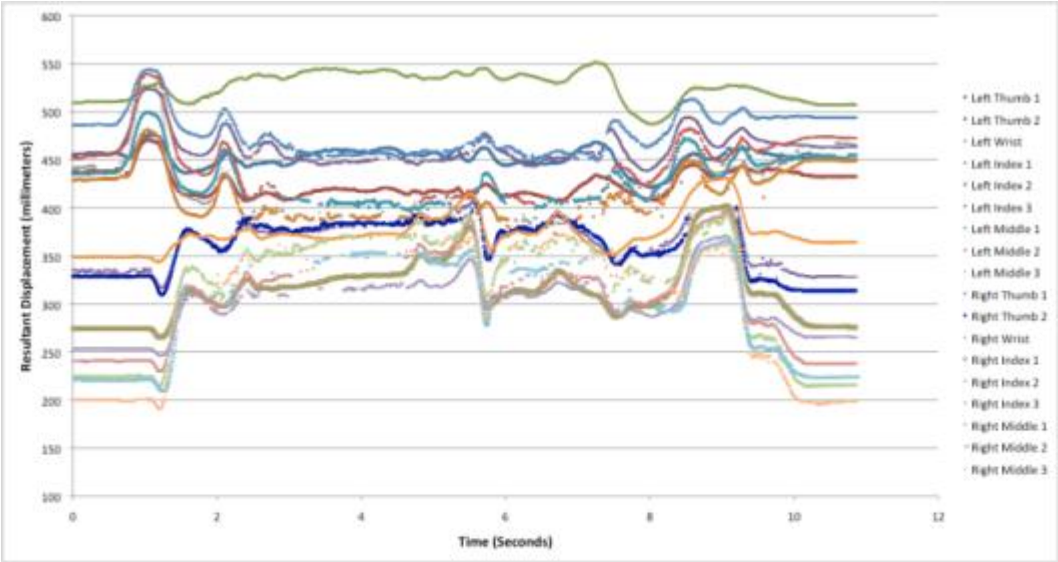


Figure 12: *Motion capture results for Grip type 2*

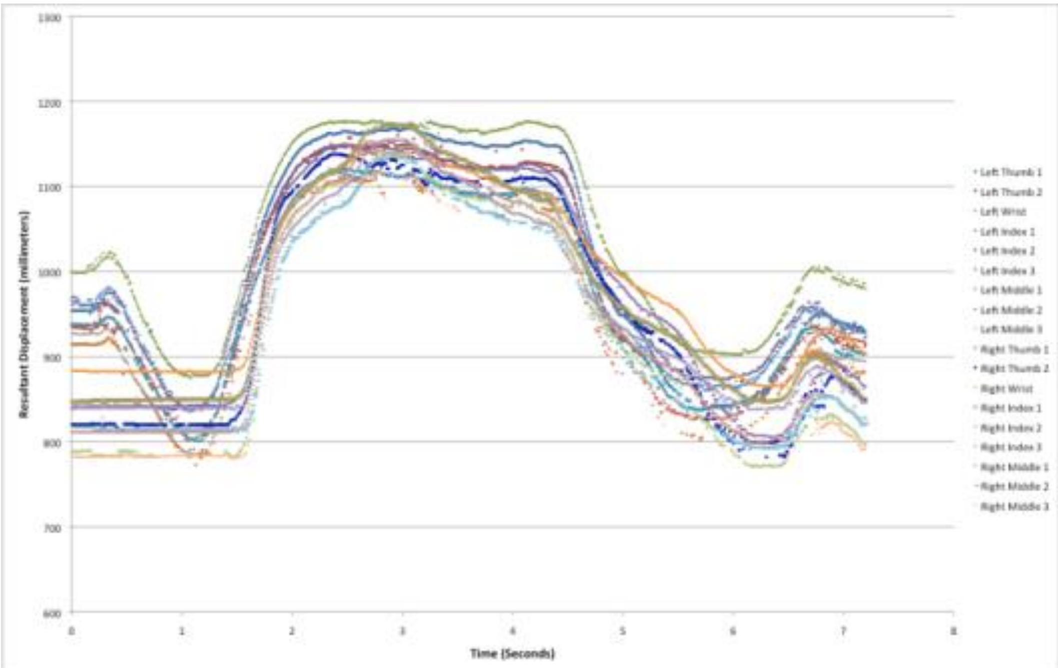


Figure 13: *Motion capture results for Grip type 3*

Table 1: Gradient and R^2 values for the Macro Dexterity data

	Oval	Circular
Best fit gradient	-0.0637	-0.0734
R^2	0.1294	0.1221

Table 2: Gradient and R^2 values for the Micro Dexterity data

	Oval	Circular
Best fit gradient	-0.035	-0.0324
R^2	0.067	0.0407