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As you like it: understanding the relationship between packing design and accessibility

A. Yoxall

Art and Design Research Centre, Sheffield Hallam University

V. Gonzalez, J. Best, E.M. Rodriguez-Falcon, J. Rowson

Department of Mechanical Engineering, The University of Sheffield

Insigneo Institute for *in silico* medicine, University of Sheffield, Sheffield

ABSTRACT

Accessible packaging is continually receiving greater attention as an ageing population becomes a primary driver behind inclusive design. As we age our strength dexterity and some cognitive functions decline. For this reason, the ease of interaction with simple tasks in daily living becomes an ever increasing concern. ISO 17480 'Packaging Guidelines' consider capability issues relating to packaging and ageing to broadly come under three areas, namely, strength, dexterity and cognition.

Significant previous work has been undertaken looking at the issue of strength on packaging accessibility, with fewer studies looking at the relationship between the physical demands of dexterity and the understanding of how to open the pack. In this previous work there has been little attempt to quantify the effect of the affordances, perceptual information and symbology and the physical demands of the pack and how this relates to accessibility. Hence this exploratory study seeks to use motion capture, and a dexterity test along with a cognitive demand test to study this relationship and any changes with age.

This research indicates that the dexterous demands of a task are linked to the cognitive demands; and thus in reaching a level of comprehension of the pack and how to access the product a subject may interact with a pack effectively.

1 INTRODUCTION

Accessible packaging is continually receiving greater attention as an ageing population becomes a primary driver behind inclusive design. For example by the year 2020 half of the adult population in the UK is predicted to be over 50 (1). As we age our physical capability naturally declines and there is some change to our cognitive functionality.

ISO 17480 'Packaging Guidelines' consider capability issues relating to packaging and ageing to broadly come under three areas, namely, strength, dexterity and cognition. Within these broad terms are also issues relating to visual ability level, skin friction and motor control (2).

To understand the problem of accessibility of packaging a number of studies have been undertaken. Langley et al., (3) developed inclusive design methodologies for consumer packaging with these methodologies generally measuring opening strengths, as well as ageing and its influence on design. Whilst this is important to understand, work by Yoxall et al., (4) demonstrated that in many instances consumers struggled due to issues surrounding dexterity as opposed to just strength. The concept of 'fiddly' packaging being an issue was demonstrated by Bell et al., (5) in their work on a patients and staff accessing food in hospital settings.

Therefore, more recent studies conducted by Rowson et al. (6) sought to understand the effects of dexterity on pack accessibility in more depth. This study by Rowson et al., began to develop a methodology to assess packaging performance in relation to dexterity that would serve as a useful tool for designers and manufacturers whereby packaging opening times were related to participants measured dexterity using a Purdue Pegboard (PPT). The PPT is a standard dexterity test, used in hand therapy and rehabilitation, consisting of a series of pegs placed in holes (or washers and collars placed on pegs previously placed in holes) and the numbers of pegs placed in a measured amount of time is purported to relate to a participant's dexterity (7). Subsequent work by Yoxall et al., (8) showed that there was a significant correlation between a participant's finger movements and perceived dexterous demand of the task. So tasks that had finger movements where the fingers moved in a similar pattern at the same time were considered less dextrously demanding than tasks where the fingers moved separately. The work also showed that finger speed and smoothness were not related to a participant's perceived dexterity.

Following on from research around and strength and dexterity, another primary area of research in packaging accessibility is cognition. This relates to perception, planning and preparation, and can be defined as the acquisition and application of knowledge, comprehension, understanding and memory combined with experience via the senses (9). The perception and understanding of products and human interaction has been largely studied in the field of psychology and product design and recently spawned an entire research field of human computer interaction (HCI).

That objects have functional meanings to an observer was first proposed by Gibson (10) in the late seventies. Gibson gave rise to the term *affordance* to describe an objects and its relationship with the user. This concept was further developed by Norman (11,12) who produced a narrower concept of *perceived* affordances, whereby an objects shape, features or tactility have the ability to frame an action in the individual, i.e. a pull tab on a yoghurt pot informs us to peel the lid etc.,

A significant study looking at this issue in the area of packaging is the work by de la Fuente et al., (13). Here the researchers explore the understanding of 'affordances' by users when interacting with packaging and offer a methodology that seeks to improve packaging design by using a task analysis approach and understanding context of use and how redesign of the pack against this understanding can improve pack performance and usability.

Clearly there is a relationship between the affordances of the pack and the perception of those affordances by those individuals. Work by Theobald (14), has been used to understand the role of models within the design process. This works examines the use of mental models in the design process, in which a designer will create a conceptual model of the product that they intend to produce. This becomes the design model and represents the designers' understanding of the functions that an object must perform. 'The design model is said to be communicated through the system image, which is the end product of the designers' work' (14). The end-user of the product then develops their own mental model of the product through interaction and use. In this study the 'design model' was determined for each pack through discussion with packaging design professionals.

Hsiao-Chen and Kuohsiang, (15) in their work propose that a combination of affordances perceptual information and symbology are required to successfully develop products that work as intended, reducing the deviation between design intent ('design model')and user behaviour ('user model').

However, in this previous work there has been no attempt to quantify the effect of the affordances, perceptual information and symbology with the physical demands of the package and how this relates to accessibility. Hence this exploratory study seeks to use motion capture, and a dexterity test along with a cognitive demand test to study this relationship and any changes with age.

2 METHOD

Seven healthy subjects (4 female, 3 males, aged between 20 -70) were involved in this initial feasibility study with participants were selected from networks familiar to the researchers. The female participants were spread across the full age range with one participant aged 20, one aged 34 and two older participants over 70 years of age, whilst the male participants were all aged between 20 and 22. Whilst a small cohort, this number is typical of studies involving motion capture covering the population range (16), and it is as noted above and in the further works section, that this study was exploratory in nature and we would expect to sample a larger population in future studies. Further, whilst it is recognised that men are nominally less dextrous (Desrosiers et al., 17) we skewed this study with female participants as women are generally more likely to struggle to open packaging than males (18). Due to the exploratory nature of the study the sample selection was based on obtaining enough data to test the feasibility and validity of the method.

The study was approved by the Ethical Committee of the University of Sheffield (Sheffield, UK). Participants were informed about the protocol and signed a consent form prior to the acquisition sessions.

The experimental protocol included a series of sub tasks, see figure 1, for each part the subjects were requested to sit on a chair at a desk to complete the task. It was important to use real packaging examples throughout the test in order to form true associations between behaviour and ability (14). The different aspects of the protocol then seek to benchmark ability (stage 1) then measure; cognitive demand measured (stage 2i) and perceived (stage 2ii), and dexterous performance (stage 3).

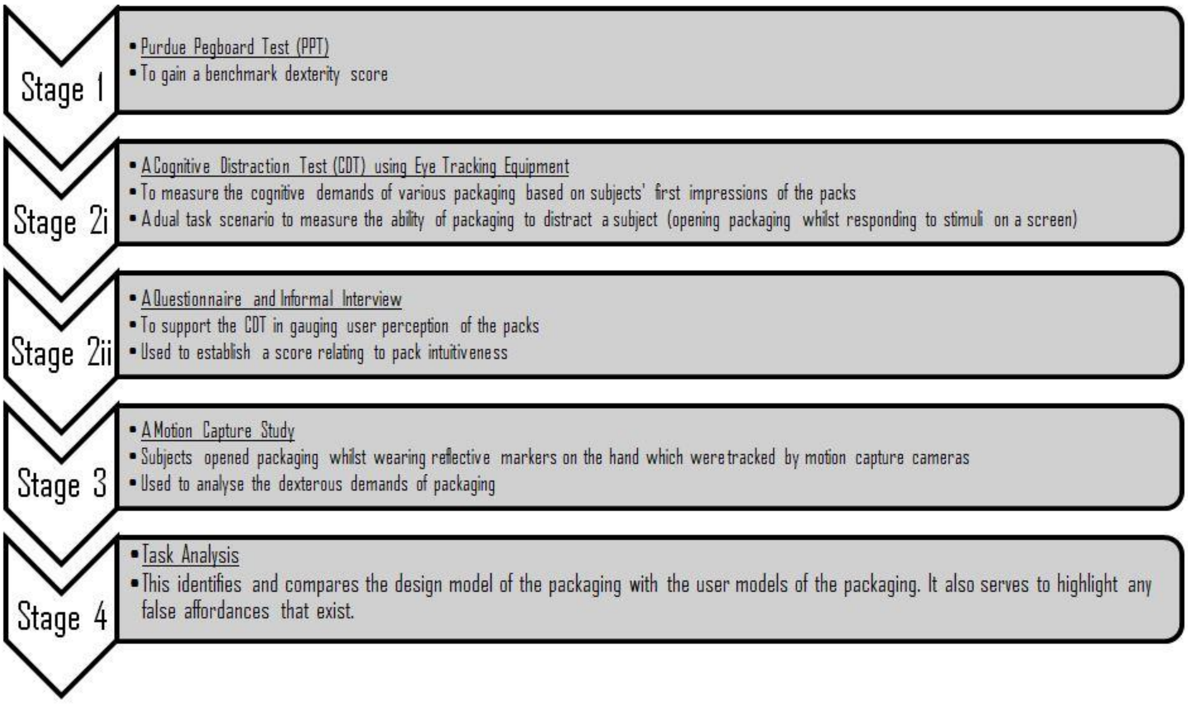


Figure 1 - Experimental Process

Stage 1: Purdue Pegboard Test (PPT) - The purpose of the PPT is a means of comparing dexterity across a range of subjects and produces a simple score. Each subject was required to pick and place pegs and position them in corresponding holes, from left to right with their dominant hand. The Purdue Pegboard (PPT) is one of the most widely used tests of hand function for therapy, rehabilitation, and treatment assessment purposes. It was developed by Dr. Joseph Tiffin, an Industrial Psychologist at Purdue University, in 1948 (6), and originally intended for assessing the dexterity of assembly line workers.

The PBT tests the quality and the speed of performance of the hand as the person accomplishes a task. More precisely, it assesses proficiency of one particular grasping pattern, the precision grip (19).

Stage 2i: Cognitive Distraction Test (CDT) - A cognitive distraction test (CDT) was developed as a means of assessing cognitive load during interaction with various packaging. Six package formats were chosen, with a variety of opening styles, package intuitiveness (with both strong and weak affordances), implicit/explicit affordances and visual clues represented, see figure 2. The chocolate and foreign packaging were chosen to be unfamiliar to the subjects, as the chocolate was in a new style of packaging, which had been on the market less than 1 year. The test was designed in order to establish the ability of various packaging to distract a user from a secondary task. The test was derived from a similar test used by the Association for the Advancement of Automotive Medicine (AAAM) (20).

Figure 2 - Selected Packaging

Distraction can be broadly categorized into visual and cognitive demand. The setup of the CDT enabled measurement of both of these elements in order to build a picture of the level of mental effort required to open each of the various packages. In a similar setup to the one used by the AAAM (20), visual task loading and the visual demands of packaging was measured using eye tracking equipment.

For the experimental protocol a screen was placed in front of subjects and random numbers from 1-10 would appear on the screen in intervals of 1.5 seconds. Firstly, a control test was completed and subjects were asked to verbally repeat the numbers on the screen as soon as they appeared. This did not involve opening any packaging. Their verbal responses were recorded and the response times (the time between the number appearing on the computer screen and them verbally announcing the number) was measured to understand how quickly and consistently they were able to respond.

The test was then subsequently repeated, with packaging introduced as the primary task in a dual task scenario. Subjects were asked to attempt to open packaging whilst also attempting to verbally repeat the numbers as they appeared on the screen in the same format as they had completed in the control described previously. Further, eye tracking equipment was used to support a greater understanding of the visual demands of packaging by tracking gaze data enabling measurement of the number of times a user deviated from the screen and the amount of time they spent looking at various packaging, see figure 3. The eye tracking equipment used was the Tobii eye tracking glasses version 2.0 with the Tobii Pro Glass analyser (21). Combined with the response times and response rates, these measurements helped build a picture of the cognitive demands of various packaging and the level of mental effort exerted in each case.

Figure 3 - Images Showing the CDT Setup

Stage 2ii: Questionnaire - Proceeding from the CDT, subjects completed a questionnaire rating the various packages, their own opening habits and how they felt the designer intended them to open the packages and why. The questionnaire showed pictures of the packs as a reminder for each pack and asked users if they had interacted with this type of packaging before. Following this they were asked to rate the following questions using a five point Likert scale similar to that used in ISO17480, packaging Accessible Guidelines, Annex D (this scale was chosen as it had been used in this standard and was familiar to the participants, in this instance the faces represented very well, somewhat well, neutral, somewhat badly, very badly):

- how well do you feel the shape of the pack aids opening
- how well do you feel the texture and material of the pack aids opening
- how well do you feel the colours and the patterns of the pack aids opening

Participants were asked if when looking at the packs they had read any instructions and looked at any symbols and then again asked to rate the following questions using a five point Likert scale:

- for each case, how well do you feel the instructions aided opening
- for each case how well do you feel the symbols aided opening

This along with a qualitative interview built up a picture of how users perceived the packaging and qualitative user generated mental models were produced.

Stage 3: Motion Capture Study - A motion capture study to measure the dexterous demands of the various packing through a kinematic analysis of the flexion angles in the joints of the hand and the correlation of finger movements was undertaken. Data was collected via motion capture, with a ten-camera Vicon T-160 system (Oxford Metrics Ltd., UK) recording the movements of reflective markers placed on a set of anatomical hand landmarks. Markers were placed on specific areas of the dominant hand according to (15), is shown in figure 4.

The markers were located such that the flexion angles for the individual fingers and thumb could be calculated in conjunction with the correlation between the various joints.

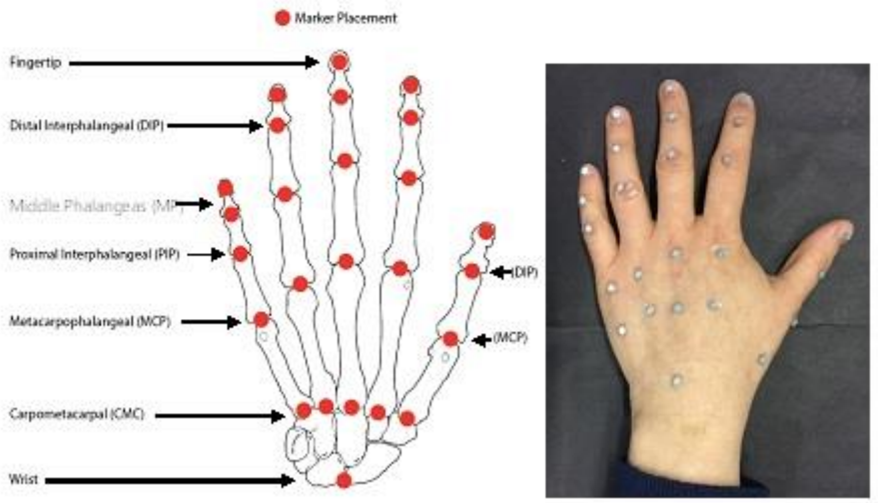


Figure 4 – Motion Capture Marker Placement

Stage 4: Task Analysis - Assessment and understanding of packaging handling can be determined using task analysis methods. While there are a number of different methods of task analyses, a simple Hierarchical Task Analysis (HTA) (Annett and Stanton, 2008, Stanton, 2005) can be used to interrogate the process of human-pack interaction. Within this work a task analysis of the various packaging tested was undertaken using observation to identify and compare the design model of the packaging, the instructions or method the packaging specified, with the user models, what the subjects actually did, when accessing the packaging.

3 DATA PROCESSING

Stage 1: Purdue Pegboard Test Data - The results were collated into a simple graph displaying the age and gender of the subject, along with their dexterity score as an average of 3 attempts. All participants' data was in line with standard normative data for age and gender (7,17).

Stage 2i: Cognitive Distraction Test Data (CDT) - The response times to the stimuli on the screen were recorded to the nearest millisecond using WavePad Sound editor. These were then analysed in conjunction with the eye tracking video to establish the number of missed values, if any, and to calculate the response rates. Finally, standard deviations were calculated to understand how the response times varied from the control.

Analysis of the gaze data and eye tracking videos recorded using the eye tracking equipment was done by tracking frame by frame. This established how many times a subject deviated from the screen and how long they spent looking at the packaging and the time to open. The video analysis was also used to confirm the number of missed values in recording the response rates. In addition, the gaze data was automatically mapped onto snapshot images at various stages of opening, in order to understand where and for how long a subject looked at the package, see figure 5.

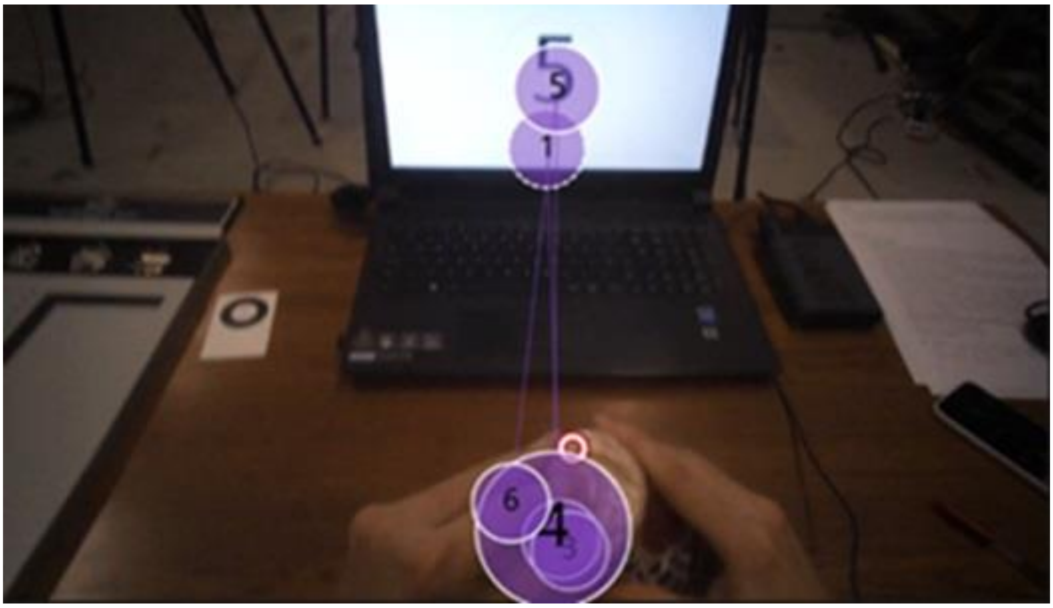


Figure 5 – Gaze tracking data example

Stage 2ii: Questionnaire and interview Data - The primary purpose was in providing a measure of package intuitiveness in relation to affordances. However it was also used to assist in developing a task analysis for each package, supported by eye tracking videos and motion capture data.

Stage 3: Motion Capture Study - Firstly, joint angles were used to establish the level of dexterous demand required by each package. The dexterous demands of the packaging was determined using two measures to look at the flexion angle severity. A study by Tagliabue et al (22) demonstrated that a precision pinch grip was accompanied by joint angles in excess of 50 degrees. Therefore, for the purpose of this research, joint angles exceeding this value were considered to be approaching severe and transitioning into the fine finger movements associated with micro dexterity.

The second measure of dexterous demand was developed based on the premise that dexterous demand increases as the sharpness of movements increases. The method developed sought to identify how often the joint angles varied by more than 30 degrees within 100 frames (1 second). This research considered any movement that required a change in joint angle of greater than 30 degrees within a short timeframe (1 second) as sharp. In instances where the change in angle was below 30 degrees within 100 frames, the movements were considered smoother.

This research utilised the Pearson Correlation Coefficient (PCC) to understand the correlation of the finger movements relative to each other. The PCC produces values between -1 and +1.

The closer the value is to -1 or +1 the stronger the correlation with a value of 0 indicating no correlation.

In order to collate and compare the data from the correlation maps, a graph was produced that compares the number of occasions where the correlation was below 0.5, weakly correlated, and above 0.85, strongly correlated. This corroborates the methodology used in a study by Yoxall et al (8), in which the same scales are employed.

4 RESULTS AND DISCUSSION

4.1 Response times and rates

The response times and response rates are presented for the dual task scenario and shown in figure 6. The average control response time is also shown in this figure from the CDT test where no packaging was presented to the particiapnt. When various packaging required more cognitive and visual attention, subjects found they had to deviate from the screen more often, thus often increasing their response times to the numbers appearing on the screen. Moreover, in highly demanding scenarios, numbers were missed altogether and their response rate decreased.

The graph below demonstrates this process. In the cases of the Weetabix, pens, and crisp packets, no numbers were missed so the response rate remained complete. The standard deviation between the response times was low, as indicated by the few peaks and troughs and the data points sitting close to the horizontal line of the control. However, with the remaining 3 packages, subjects had to deviate from the screen much more often and their response rates decreased indicated by the red points on the graph. At this point, the standard deviation became less of a useful measure and the numbers of values missed became the primary measure of cognitive demand.

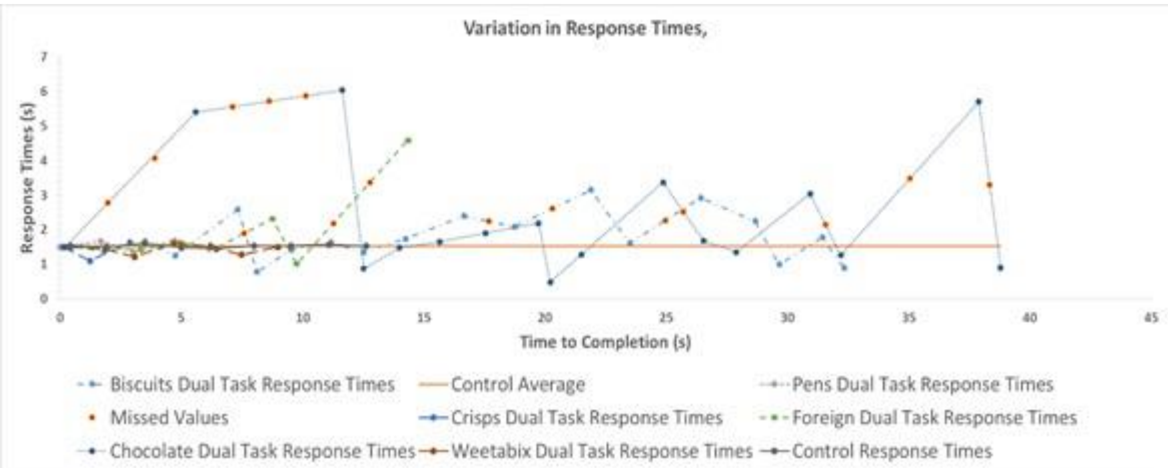
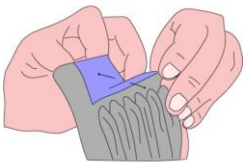
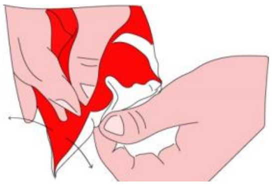


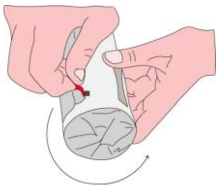
Figure 6: Response times during the CDT

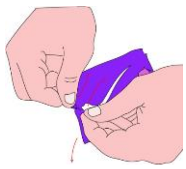
4.2 Task analysis

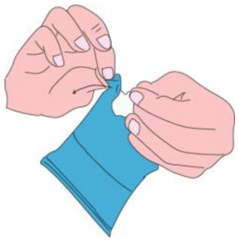
The first product of this research work is a task analysis of the various packaging tested. This uses observation to identify and compare the design model of the packaging, the instructions or method the packaging specified, with the user models, what the subjects actually did, of the packaging. It also serves to highlight any false affordances that exist. The

Intended (Design Model)	**User Models (if different)**
Pens	
 1. Pick up the pack 2. Hold pack with one hand whilst prying a corner away from the backing, primarily with the index finger of the second hand 3. Moving the hands in opposite directions separates the front plastic from the card backing	

Intended (Design Model)	User Models (if different)
Crisps  1. Pick up the pack 2. Grasp top of pack (end seal) between the thumb and index finger of both hands 3. Pulling apart the two hands in opposite directions whilst grasping the top of the pack breaks the seal	

Intended (Design Model)	User Models (if different)
Biscuits  1. Pick up the pack in non-dominant hand 2. Grip tear strip along the fin seal of the pack between the thumb and index finger of the dominant hand (indicated by notches & red tear tape) 3. Whilst gripping the tear strip, move the dominant hand around the circumference of the pack in a circular motion to tear through the material	 1. Pick up the pack in non-dominant hand 2. With the thumb and index finger of the dominant hand, grip the overlapping material at the end seal 3. Pull the material away from the pack to expose the product (envelope opening)

Intended (Design Model)	User Models (if different)
Chocolate  1. Pick up the pack in dominant hand 2. Grip the two layers of material at the fin seal on the back of the pack between the thumb and index finger of both hands 3. Peel the two material layers apart by moving hands in opposite directions to reveal the product	 1. The red arrows indicate unsuccessful opening methods attempted by subjects 2. Attempting to rip the entire fin seal away from the pack 3. Attempting to tear through the material by gripping the end seal with the index finger and thumb of both hands and pulling apart in opposite directions

Intended (Design Model)	User Models (if different)
Foreign	
	
1. Pick up the pack in non-dominant hand 2. Holding the pack with one hand, grip the corner of the pack at the point indicated by a notch between the thumb and index finger of dominant hand 3. Tear the corner of the pack down along the side of the pack to reveal the product	1. The red arrows indicate unsuccessful opening methods attempted by subjects 2. Attempting to open the pack like a packet of crisps by gripping the end seal between the thumb and index finger of both hands and pulling apart in opposite directions

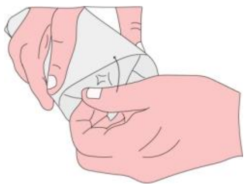
Intended (Design Model)	User Models (if different)
Wheat bisks	
	
1. Pick up the pack in non-dominant hand 2. With the thumb and index finger of the dominant hand, grip the overlapping material at the end seal 3. Pull the material away from the pack to expose the product (envelope opening)	

Table 1: Task analysis of each package

The user model for the pens and crisps did not vary from the design model. The crisps scored highly on the intuitiveness rating and the pens slightly lower, showing that both packs were easily understood and afforded opening as per the design model.

Subjects encountered a few problems with the biscuit package. The majority of subjects looked for the tear tape based on past experience. However, it was often the case that the subjects could not find any indication of the tear tape’s location and in the instances it was found, the tear tape did not always work. Therefore, the user model often differed from the design model with subjects attempting to open the package from the top.

Both the chocolate and foreign package scored low on the scale of package intuitiveness as neither were immediately understood by subjects. Although the chocolate package was explicitly marketed as easy open, the unfamiliar opening style meant that cognitive and dexterous demands were relatively high, and the package not easily understood. Out of the 3 subjects that were familiar with the peel and reveal package, only one subject opened the package as per the design model and instructions. From the CDT and the questionnaire the foreign package afforded opening like a packet of crisps. This is due to the package appearing to have similar features compared to a crisp packet. Therefore, the common user method of opening in all cases was to first attempt to open the package in this manner. However, this is a false affordance and does not afford effective opening as the materials largely prevent this method of opening. Two subjects managed to open the package in this way but required to bring it close into the body, apply significant force, and in one case the product was subsequently scattered across the table. The design model for this package relates to a simple tear via a notch in the top corner of the package. After failing to open the package via the false affordance, two subjects did manage to eventually locate the point at which to tear. The evidence from the gaze data, the CDT, the questionnaire, and the task analysis, suggests that this package is fairly unintuitive and cognitively demanding.

The Weetabix package is interesting to compare with the chocolate package. The package is marketed as easy open, however, where or how the pack is to be opened it is not displayed anywhere on the package. Instead, Weetabix rely on the package being fairly intuitive and focused their energy on ensuring the materials could be torn as easily as possible, having experimented 'with hundreds of different types of paper and packaging options to find the perfect replacement for the plastic wrapper' (23). However, due to the nature of the closure, the Weetabix package was quite dexterously demanding. This is due to the fine finger movements and micro dexterity that is required in order to grip the top material layer which lays flat to the top of the package.

4.3 Dexterity Scores

The results from the Purdue Pegboard Test (PPT) range from 12 – 20, see figure 7 and are in line with standard normative data for age and gender (7,17). Although subjects' dexterity scores decreased with age, when the various packages were tested it was observed that the main barriers to package accessibility surrounded cognition rather than dexterity. The dexterous demands of the packages also seemed fairly consistent across the age range with elderly subjects able to perform the actions of opening without issue, once the packages were understood. None of the subjects appeared to struggle in forming any of the necessary grips required to open the packages, or in applying the necessary strength.

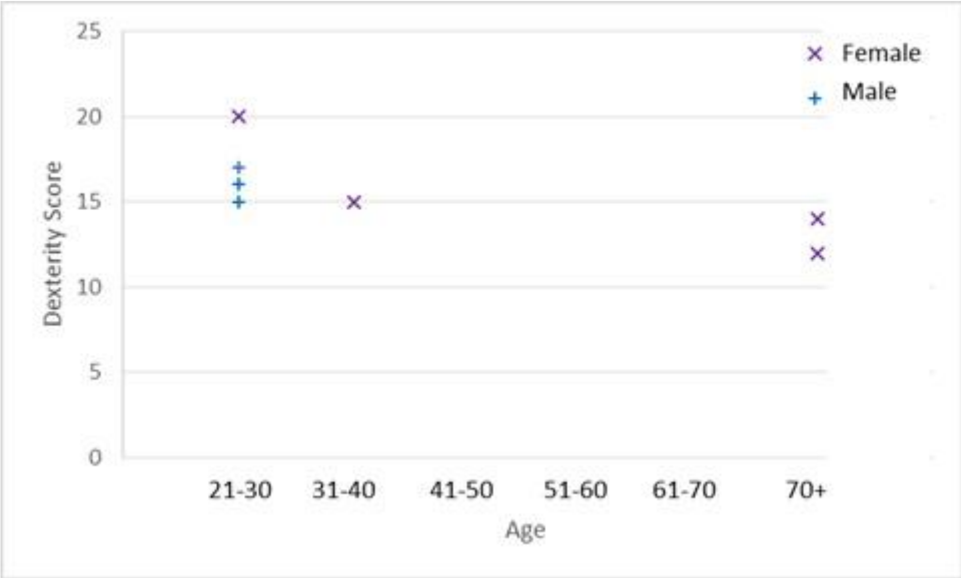


Figure 7 - Graph Showing the Dexterity Scores from the PPT

Where the packages were opened successfully across the age range, there was a consistency with regards to the grips formed and the time taken to open the various packages. Where subjects experienced difficulties, it was largely due to false affordances and misconceptions of the packages combined with low package intuitiveness.

4.4 Questionnaire Results

The results of the qualitative research conducted using the questionnaire and an informal interview found that crisps scored the highest, largely due to low cognitive demands and a high level of familiarity the subjects experienced with the package. The Weetabix package also scored highly and was easily and immediately understood by subjects. Both the crisps and Weetabix had strong, implicit affordances which aided accessibility and enabled the subjects to comprehend the package on a more subconscious rather than conscious level. This is reiterated by the results of the CDT which showed these packages demanded less visual attention compared to the others.

The pen package and biscuit package scored lower in relation to intuitiveness. The materials and nature of the closure of the pen package in particular meant that there was slight hesitation amongst subjects as to where to tear, relating to individual corners and whether opening via the front or the back was most efficient. The biscuit package scored moderately because as the tear tape was often difficult to locate, subjects thought that it was not present and were lured by the false affordance of opening via the top.

The foreign package, whilst fairly implicit in nature, was not intuitive. The affordances of the package was weak and the false affordance of opening like a crisp packet rarely led to opening. The majority of subjects only truly understood how to open the package, as per the design model, after they were able to analyse and discuss the package in greater detail.

Finally, the chocolate package scored the lowest in terms of intuitiveness. On first impressions, few subjects fully and immediately understood how to open the package. Moreover, the main affordances were explicit in the form of instructions and symbols. In order for an explicit affordance to be effective it must strongly afford opening as otherwise its presence is meaningless. However, this was a relatively new opening design using a peel function in place of previous methods to open this type of package as such the intuitiveness of the packaging was weak and afforded multiple incorrect methods of opening. The results can be summed up in the following illustration, see figure 8.

Figure 8: Illustration of the strength of affordances for each package and their overall intuitiveness.

4.5 Flexion Angles

Using motion capture data, flexion angles for all the joints of the hand over time were developed for each subject and each package, see example of whole hand opening the chocolate package in figure 9. There were 42 graphs in total and as such, the dexterous demand graphs detailed below enable a means of comparison.

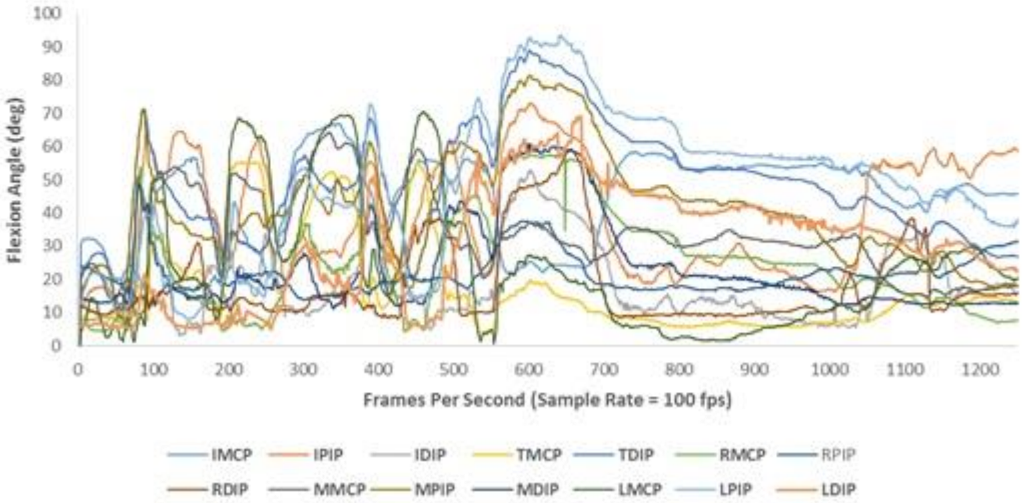


Figure 9 – Whole hand flexion angles for single participant opening chocolate package

Correlation maps were produced to show the correlation between joints in the hand, see figure 10. The scale is such that a score of 1 indicates highly correlated movements, and 0 indicates no correlation of movements. From the maps it can be seen that whilst subject 7 used a highly correlated movement of their hand during the opening, subject 6 movements were largely uncorrelated and thus indicating a much more complex and less dexterous movement on the individual joints.

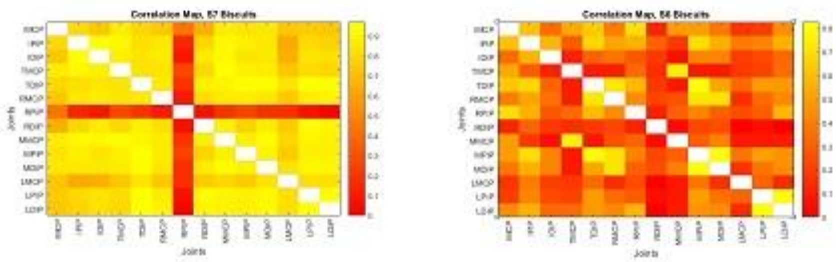


Figure 10 – Correlation maps for subject 7 and 6 respectively, opening biscuit package

Dexterous demand ratings were developed to enable comparisons to be made between flexion angles across the various packages. Results indicated there was no significant variation in the dexterous demands of the packages across the range of subjects, therefore in considering the dexterous demands of packaging, any meaningful comparisons were drawn from the averages across all the subjects as opposed to individual comparisons between the various age groups.

The graphs below, see figure 11 and 12, show the mental effort exerted during the interaction and opening of the various packages. The image on the top left shows the breakdown of the several measures as per a deductive scale. The possible deductions were out of 100% and each package was compared relative to the others. Figure 11 shows the total mental effort exerted, or total cognitive demand, with the outer rings demonstrating high exertion and demand. Figure 12 shows more detail, showing the chocolate package consistently required a high demand, whereas other packages for example the Weetabix pack, were high in a single demands such as opening time. The pens, Weetabix, and crisps were the least cognitively demanding and were the easiest to understand. These results correlate well with the qualitative results from the questionnaires that established package intuitiveness.

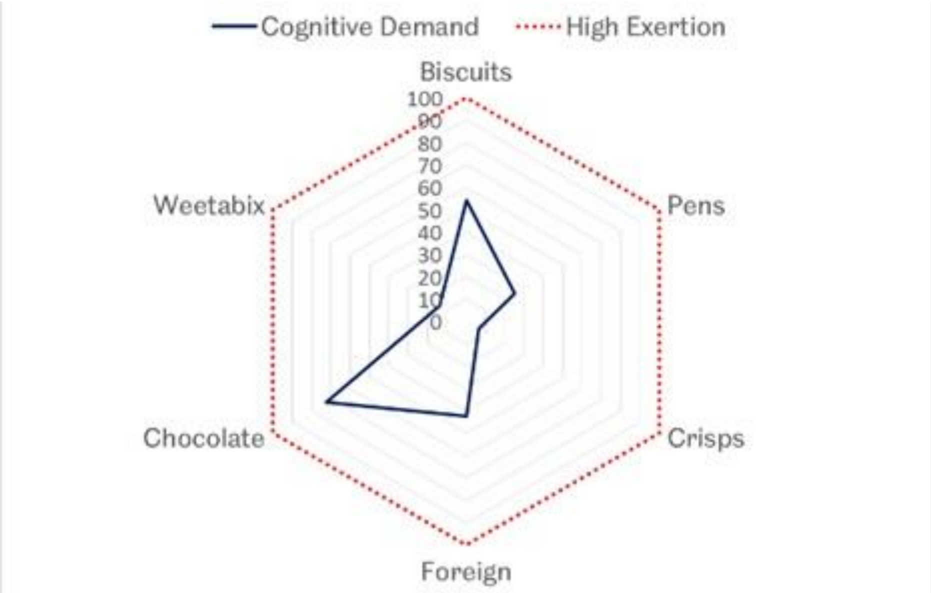


Figure 11 – Average total cognitive demand of each package

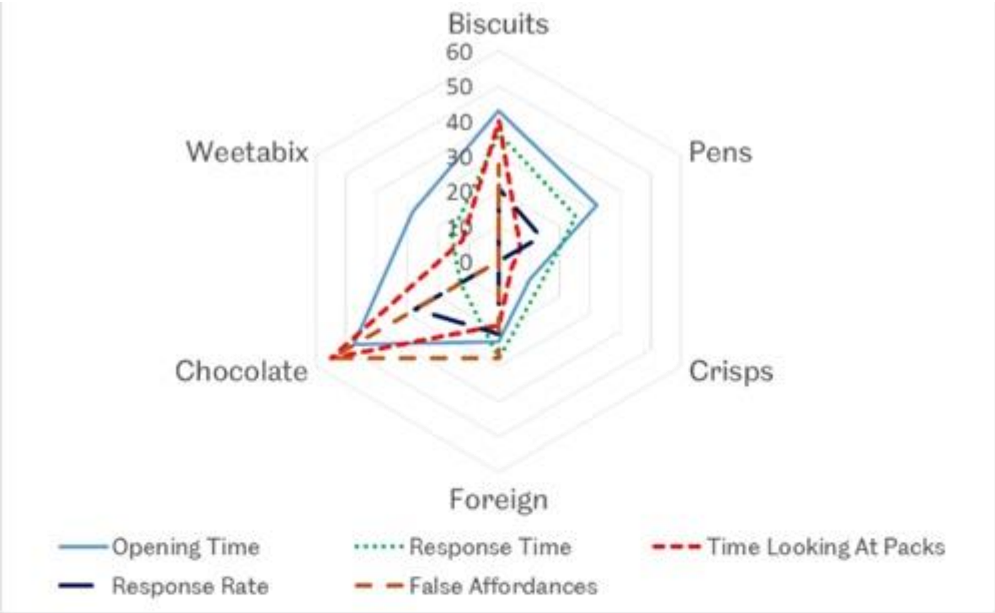


Figure 12 – Average cognitive demand broken down into demand categories

It is appropriate that the more intuitive packages were less cognitively demanding. As discussed previously, the ability to complete both tasks in the CDT simultaneously did not pose significant problems for the more intuitive packages; the crisps, pens and Weetabix. However, where false affordances were present in the other 3 packages the following observations can be made:

- Time spent looking at and opening the package increased
- Subjects became confused which decreased their response rates to the stimuli on the screen and decreased their ability to complete both tasks of the CDT simultaneously
- Subjects deviated from the secondary task more often

In comparing the cognitive demands of the various packages across the age range, it was observed that the elderly subjects found the cognitively demanding packages most difficult to open.

Dexterous demand ratings have been developed based on two sets of criteria. Firstly, severe joint angles as a percentage of the total joint angles was established. This is a measure of how packages compare in relation to macro and micro dexterity. Macro dexterity may be defined as gross finger movements and is accompanied by low joint angles (<50°), whereas micro dexterity may be defined as fine finger movements and is accompanied by high joint angles (>50°) (16). The second criteria relates to the sharpness of the movements of the hand, labelled joint angles exceeding 30° in 100 frames. This provides a measure of how smooth the relative movements are. The greater this value, the less smooth the manipulation of the fingers is. Both these criteria were measured across the packages and averaged out across subjects. The results can be seen in the graph below.

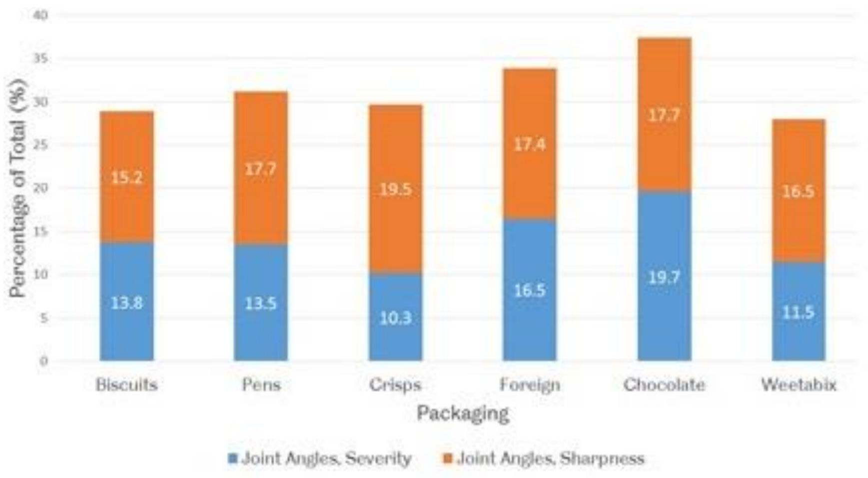


Figure 13 - Average Dexterous Demands of the Packaging

From figure 13 it can be seen that in relation to the overall dexterous demands, as per the two criteria, the chocolate and the foreign package score the highly indicating high dextrous demand. This is understandable as both packages require tight manipulation of the fingers in forming a precision grip as can be seen in the task analysis above. The chocolate package requires the user to pinch the layers of material between the index finger and thumb and the natural position of the remaining fingers is to curl around in a similar manner to the index finger. This results in a relatively high proportion of severe or high joint angles relative to the whole task of opening. Similarly, the foreign package requires a precision grip in order to tear away the corner of the package.

The Weetabix package is the most accessible in considering the total dexterous demands. This appears to be down to fairly low joint angles involved in opening the package. Whilst a precision grip is initially required to lift the material away from the top surface of the package, it was observed that subsequent steps simply involved easing the 4 corners away from each other, which did not require fine finger movements.

This graph is also corroborated by observations in the motion capture study that showed the action of opening the biscuit package to be fairly smooth once the tear tape had been accessed. Consequently, it follows that this would score the lowest in relation to the sharpness of movements.

The crisp packet had the lowest severity of joint angles which is understandable as the opening method relies primarily on the thumb and index finger and the remaining fingers are not often used.

Finally, the pen package scores moderately across both sets of criteria. In relation to dexterous demands it lies somewhere in the middle of the other packages. This is also the case in relation to the cognitive demands and the intuitiveness of the packaging where the pens seem to score moderately across the board.

5 CONCLUSIONS

From this initial research it can be seen that the dexterous demands of a task can be linked to the cognitive demands; in reaching a level of comprehension through which a subject may interact with a package effectively and with strong understanding. By comparing the different packaging results for individual subjects these links may be explored by considering the following observational statements.

- The more intuitive the package, the lower the cognitive demands
- The lower the cognitive demands of the package, the greater the understanding
- The greater the understanding, the more effectively and efficiently a package is opened
- With increased effectiveness and efficiency, as per the design models of the packaging, the dexterous demand may be decreased
- All this combined; the lower the cognitive and dexterous demands, the higher the accessibility

This research has successfully identified and tested multiple variables and factors that are important in the ability to access packaging. In considering truly inclusive design, exploring these factors may help designers build a real picture of user interaction with their products. Using empirical studies and assessing packages in actual usage scenarios, it is possible to create a clearer user generated mental model of packaging to compare with that of the design model.

As stated earlier Hsiao-Chen, and Kuohsiang, (15) in their work proposed that a combination of affordances, perceptual information and symbology are required to successfully develop products that work as intended, reducing the deviation between design intent ('design model') and user behaviour ('user model') and this work identifies that in the packages measured where the perceptual information, symbology and affordances are confusing or demanding for the consumer, the package is likely to score badly in terms of accessibility.

Methods like the one laid out in this report may enable designers to repair what could, in some instances, be referred to as a broken feedback loop, through which user feedback has not previously been effectively communicated and measured. The varied qualitative and quantitative measures employed and combined in this research may hopefully serve as a benchmark for future packaging design.

6 Future Work and Limitations

This preliminary study has gone some way to establishing the difference between design and user models for opening packaging. Future work is needed to characterise the population through a larger study to include all abilities as whilst differences were found between packages, no significant difference was found between the populations measured. At that stage it would be advisable to include a control opening task before coupling it with the CDT. It would also seek to study the effect of exposure to an opening model, through familiarity affects the results compared to unfamiliar models. It is supposed that whilst newly developed packaging may be physically easy to open it has a significant cognitive demand as the method is being learnt.

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