Randomness as a CAD Tool for the Affective Augmentation of Form in Product Design Concepts

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Copyright Statement

Abstract

Computer tools for design are frequently employed in an attempt to improve efficiency and reduce time to market. More recently, attempts have been made to develop CAD tools for emotional design. Such tools may be intended to augment the emotional responses elicited by a product's design and, in so doing, attempt to achieve market supremacy. This research primarily investigates one way in which CAD tools might be applied by designers during the design process, in order to attain their objectives. Particular emphasis is placed on customer perceptions, as well as the significance of designers' experiences during the design process.

A pragmatist approach was undertaken to identify the particular line of enquiry. Initially this involved a pilot study to investigate some of the ways in which people respond to products during first contact. This was followed by experimentation with the CAD software '3DsMax' in an attempt to create a basic prototype CAD tool based on verbal descriptors for emotional design. An exploratory study was undertaken to test aspects of this tool while seeking to refine the research question. Further CAD tool experimentation led to the application of constrained; randomly generated variables to drive the creation of parametric CAD models. The principle was that the addition of surprise can help designers to break free from routine approaches and that this might aid them in creating new and unexpected forms capable of eliciting emotional responses in those perceiving their designs. A final study tested the hypothesis that such an approach would be beneficial in creating product design concepts. The results largely supported the idea that randomness could be beneficial in creating emotional responses to product design and also found that designers were receptive to the premise and use of such a tool. The results of the study underpin a proposal for the use of a pseudo random CAD tool for the creation of affective product design concepts.

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I'd like to acknowledge the help and support of my supervisors: Prof. Siamak Noroozi and Dr Bob Eves. I'd also like to thank students and colleagues in the Faculty of Science and Technology for their encouragement and constructive feedback. Finally I dedicate this thesis to my family, which has provided me with support and inspiration throughout this challenging journey.

Author’s Declaration

The work embodied in this thesis is the result of the candidate’s own investigation, apart from where indicated. No portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other University or institute of learning.

Definitions

3DSMax: A professional 3D computer graphics program for making 3D animations, models, games and images, developed and produced by Autodesk Media and Entertainment

AI: Artificial Intelligence

CAD: Computer Aided Design

Manually created concept: A concept created using a CAD tool that responds to manually controlled parameters. Although technically 'manual' would more accurately describe the use of no CAD tool whatsoever, the term is used here for the purposes of brevity and distinction within this exploratory context.

Modifier: A form-manipulation effect applied to a CAD model

Modifier Stack: a list used to determine the sequence of modifier applications.

Non-random CAD Tool: A design tool that can be used to create parametric CAD artefacts directly from user controlled variables.

PDS: Product Design Specification

Pseudo-random number: A seemingly random number generated from a computer algorithm.

Random CAD Tool: A design tool that creates a parametric CAD model from pseudo-randomly generated variables.

Randomly created concept: A concept created using a pseudo-randomly generated set of parameters within a CAD environment.

SER: Strongest Emotional Response

UI: User Interface

WER: Weakest Emotional Response

1. Introduction

1.1 Origin and Inspiration

This PhD research project was undertaken within Bournemouth University's design and engineering department, which resides in the faculty of Science and Technology. The inspiration for the research came from previous research undertaken within the department. In particular, the creation of an artificially intelligent CAD tool capable of interpreting verbal descriptors to generate colour concept selections, by Dr Bob Eves as part of his PhD (Eves, 1997). In that particular case, the design and application of a dedicated CAD tool ('The Colour Concept Generator') was successful in producing colour concepts that met criteria for eliciting predetermined aesthetic responses. The initial direction of this PhD research project was seen as a progression of that work, i.e. the exploration of CAD tools to manipulate three dimensional designs to achieve an emotional affect or augment emotional responses.

1.2 Previous Research

The notion of a CAD tool that could extrapolate changes in 2D forms from associated descriptive vocabulary was proposed as part of a joint paper presented at the Engineering and Product Design Education conference at Coventry University in 2002, (Dyer, et al., 2002). The paper described the use of verbal descriptors as data inputs (e.g. words like *slender, graceful* or *chunky*) that could be interpreted within the CAD software to modify a product design's form. The emphasis of that paper was on the use of 'Artificial Intelligence' (A.I) in design and thus the development of an A.I mechanism was suggested to meet the functional objective. That paper was well received, but the work described in that paper was taken no further at the time. This PhD research project picked up where that research left off, but it is not the same project as the one proposed in 2002. However, it does share the same overall aim, which is the investigation of CAD tool applications for the creation and augmentation of shape and form.

1.3 Scenario

Designers play a leading role in ensuring that the concepts developed for production are likely to be successful in broad and diverse markets. However, producing a single design that appeals to a large proportion of the available market can be difficult. A product's form may be comprised of many elements, including composition, proportion, congruency, volume, space and so on (Hannah, 2002). A product is often a material manifestation of many qualities and attributes. Commercial product design is often a result of the collective experience of a team of skilled individuals. Their qualities combine to provide the insight and expertise necessary to deliver a successful product design. That design will doubtless encapsulate the cultural, social and functional considerations that were taken into account during the design process. It may also reflect the external influences acting upon those designers both consciously and subconsciously. A product design's success can often be attributed to the manner in which these factors were assimilated and expressed by the designers throughout the course of the design process.

Design for Emotion (or *Emotional Design*) has become an established branch of design and engineering (ENGAGE, 2005). The foundation of the idea is that people prefer using products that meet their emotional requirements as well as their utilitarian needs. Work in this field has attracted significant interest amongst design academics and practitioners and is fast becoming recognised as an important commercial factor in an ever widening and highly competitive marketplace (Karahanoğlu, 2009).

The product development process itself changed significantly during the latter part of the twentieth century. Developments in technology and computer science have enhanced the creative potential of design individuals (Bonnardel & Zenasni, 2010). With the ever-decreasing relative cost of computer hardware coupled with the increased accessibility of sophisticated CAD software, the need for hand-drawn plans and engineering drawings is largely a thing of the past. With that, the lead-time between design and production has also fallen. Time to market is a significant factor in ensuring a new product can be launched while there is still a high demand, before competitors can launch equivalent, better or less expensive alternatives. Since the introduction of rapid prototyping, the majority of designers can, in theory at least, undertake their work entirely within the CAD domain. Coupled with the power of the internet, designers are able to create almost anything they can imagine within a virtual or augmented environment and subsequently share their ideas instantaneously with colleagues and clients around the world. This PhD research project attempts to bring together this CAD domain with the objective of eliciting positive emotions from product design in a timely, cost effective manner.

1.4 Aim and Objective

The aim of this PhD research project was to investigate ways in which designers can elicit positive emotional responses from their design concepts using CAD. The more specific objective was to develop a CAD design tool (or methodology) that could bring together form and emotions. CAD is the medium of choice for many designers due to its power and accessibility. However, what it offers in functionality it can lack in terms of spontaneity and immediacy. As a result, the efficiency benefits of CAD tend to be exploited most at the detail design stage of the design process, when a basic concept has already been formed and when the rate of change has significantly reduced. It therefore seemed appropriate to look for opportunities to apply CAD tools earlier in the design process, particularly for the purpose of augmenting emotional responses to design concepts.

From the outset of this research project it was envisaged that a CAD tool (as with any tool) should be one that assists rather than automates. This could be either by helping designers arrive at a concept more quickly than they might have otherwise, or by helping them to create a new product design concept that they might not have conceived otherwise. The intention was not to remove the designer’s creative abilities but instead, to enhance their endeavours and to help make the concept generation process more productive. A particular emphasis was placed on creating concepts capable of eliciting positive emotional responses through their visual appearance.

1.5 The Research Problem

Previous research (Dyer, et al., 2002) indicated that there may be scope for a CAD tool that could interpret a designer's intentions in a quick and intuitive manner (such as through the application of verbal descriptors). The greatest challenge in providing a verbally driven CAD tool is the interpretation of the designer's subjective intentions (Giannini & Monti, 2002), which would most likely require some level of artificial intelligence. Even then, one designer's expectation of how a word should be translated geometrically could vary significantly to another's. To investigate this problem area further, a pragmatist approach was adopted in order to formulate a research question. An initial pilot study was undertaken to try to gain a better understanding of the way product designs are perceived when seen for the first time. An exploratory study was then devised to integrate the findings of the pilot study with the initial development of a verbally driven CAD tool. The outcomes of the pilot study and exploratory study led indirectly to the formulation of the research question.

It was acknowledged that misinterpretation of design intentions could lead to unpredictable and unexpected results. However it was hypothesised that this unpredictability may in itself be considered useful to designers in the right context, since the surprise elicited could be conducive to creativity (Gonzalez , 2005). Findings from the pilot study and the literature review both suggested that surprise could have a positive effect on the elicited emotional response. The use of randomly generated variables within parametric constraints was proposed as a means of constructing CAD geometry to create surprising product design concepts early in the design process. Perceivable benefits of such an approach might be that it could enable designers to explore a greater breadth of possibilities (in less time). Furthermore, by incorporating randomness within the design process the likelihood of adopting familiar or mechanistic routines might be reduced. A refined overall research question was therefore posed:

Is a pseudo-random CAD tool an effective way of generating affective product design concepts?

Null hypothesis: A pseudo-random CAD tool would be an ineffective method of generating affective product design concepts. However, the question encompasses a number of constituent aspects and so was expanded to investigate those further:

a. **What differences can be observed between the likeability of randomly and non-randomly generated concepts?**

Null hypothesis: No difference will be observed. This was considered significant as there would be no purpose in generating product design concepts randomly if they were not considered to be sufficiently appealing.

b. **What relationships can be observed between the strength of elicited emotional response and the likeability of a design concept?**

Null hypothesis: No relationships will be observed. A strong or weak emotional response could be positive, negative or the response might be neutral. It is of interest whether a product design concept exhibiting anything other than a significant positive emotional response would be considered appealing.

c. **Does the strength of elicited emotional responses differ between randomly and non-randomly created concepts?**

Null hypothesis: No difference will be observed. This line of enquiry would investigate whether there is anything to indicate that random or non-random concept creation has any direct influence on the strength of the emotional response elicited by a product design concept.

d. **Does the application of a pseudo-random CAD tool affect the designers' experience?**

Null hypothesis: No effect will be observed. This was considered to be important because the designer is the individual responsible for delivering the final product design. If their experience was in some way diminished or compromised then that could have an effect on the end result or the usefulness of such a tool.

e. **Can the CAD tool be used to identify particular geometric features that elicit strong emotional responses?**

Null hypothesis: No particular features can be identified using the CAD tool. As a design methodology, the outcome from this research should have relevance across a wide range of potential product types and genres. Different product designs would require the application of different features and tool sets during the concept creation process. There should be a means of appraising the effectiveness or ineffectiveness of those features to help optimise the suitability and value of the resulting product design concepts and, hence, the methodology.

1.6 Thesis Outline

The remainder of this thesis is broken down into four more chapters. Chapter two is a review of existing literature associated with this PhD research project. The content of that chapter is intended to provide both a context for the research as a whole, as well as an overview of relevant contemporary research in the field of Design and Emotion. Theories of emotions are discussed along with the relationship between design and emotion, which is explored in relation to associated established strategies and tools.

Chapter three outlines the methodology used to refine and answer the research question. It describes the strategy that was implemented to meet the research objectives. The methodology involved three distinct studies within an overall pragmatist approach. The first two studies were used to refine the research question while the third was a more detailed study which sought to provide answers to the various aspects of the research question. The chapter provides details of the methods used, including detailed descriptions of the studies' procedural parameters.

Chapter four presents the results of the three studies outlined in the methodology. It includes analysis of the data obtained from the pilot study, the exploratory study and finally the main study. An evaluation of the results is provided at each stage, along with discussion of their implications on the overall PhD research project.

Chapter five presents the conclusions and recommendations made following evaluation of the research findings. These are set within the academic context of the research. Ideas for future development of the project are proposed as recommendations for further research.

2. Literature Review

2.1 Introduction

This chapter reviews existing literature considered to be of most relevance to the aspects of this PhD research project. The material focusses on discussion of three main elements, namely: Emotions, Design Process and Computer Tools. These are, in themselves, very broad and so this review is intended to represent a condensed account of those topics in relation to the research questions. However, an attempt is made to provide an overview of the research setting, to provide a contextual framework. Further to this, each element is broken down into what is considered the main constituents of the research questions.

The chapter begins by briefly discussing the nature of emotions from different perspectives. These include physiological, psychological and philosophical disciplines. This account is summarised to provide context, but also in an attempt to better understand why and how people experience the sensations and feelings that they do.

The design process and design methods are considered from a practical perspective. Research in the field of Design and Emotion are included as a specialism within design and engineering. In the context of this research, the term ‘Design and Emotion’ is used in relation to the physical appearance of an object and the way that affects the observer. The role of design methods in enhancing the designer’s creativity is of significant interest, not least the opportunities that can be created through chance and the use of randomness to achieve unexpected results.

Technological advances in the field of computing have had a major impact on the way designers work. Inevitably, this technology has permeated the various branches of design and engineering. Commercial CAD tools have become available for a myriad of applications, including sustainable design and design for manufacture. CAD tools for emotional design are less common, but developments in the field, their potential and their shortcomings are discussed.

2.2 An Overview of Emotions

The question ‘what is an emotion’ must inevitably be asked when seeking to elicit emotional responses from product design, even though it is not necessarily a straightforward question to answer. In the context of this research, the role that emotions play in influencing aesthetic preference and product selection may be considered crucial. It is evident that emotions can be described from philosophical, physiological and psychological perspectives. In the context of this research, the way in which emotions are elicited from encounters with product form is considered to be of greatest significance and, in particular, to what extent those emotions influence the way we perceive a product’s design (i.e. favourably or unfavourably).

The term ‘emotional’ is often used as an alternative to ‘affective’ (Picard, 1997). Affect being the effect of an appropriate stimulus on one’s senses. Edward Titchener refers to the concept of ‘affect’ as a pleasantness;unpleasantness dimension of feeling (Titchener, in Schutte 2005). DeLancey suggests a more sophisticated amorphous structure however, that encompasses both emotions and moods (DeLancey, in Schutte 2005), with moods being considered long term affective states rather than direct responses to events (Picard, 1997). Ciccarelli and White define emotions as “the ‘feeling’ aspect of consciousness, characterized by three elements: a certain physical arousal, a certain behaviour that reveals the feeling to the outside world, and an inner awareness of the feeling” (Ciccarelli & White, 2012). Damaisio (1995) suggests that ‘feelings’ reside at a lower level of consciousness. He determines that feelings are more directly connected to physiological properties. As a result, feelings are less subjective than emotions, albeit possessing the capability to develop to evoke emotional responses. Emotions have been described as the antithesis to reason (Damasio, 1995), in the way that a gut feeling may appear to have no logical explanation. Damasio proposes that emotions are in fact integral to reasoning. So while it might be considered irrational to prefer a functional product based on aesthetic merits, emotions must play a part (at least to to an extent) in the decision making process.

Our senses, such as smell or touch, can readily be explained physiologically. Depending on the context of sensation, it ought to be possible to anticipate the range of emotions triggered as a result of a physical encounter, e.g. touch may elicit comfort, joy or desire; the smell of burning may elicit excitement, fear or alarm. It is suggested that humans have evolved an inherent attraction (and revulsion) towards certain things from birth, as a result of natural and sexual selection (Dutton, 2003). Charles Darwin (1809-1882) proposed that emotions evolved because they had adaptive value. He believed that facial expressions of emotion are innate and that they allow people to quickly determine and communicate someone's intentions (hostile or friendly). Darwin's theory of natural selection implies that (amongst other things) those members of a species that learned to interpret vital signs within nature's rich visual language were more likely to survive and prosper over those that did not. In terms of attraction, this might include recognising a preferential habitat, identifying a suitable mate and finding food. On the other hand, a healthy fear of dangerous animals or an ability to detect bad or poisonous food could make all the difference in life and death situations.

William James (1890) and William McDougall (1908) believed that much of mankind's innate behaviour was instinctive, related to reproduction and self-preservation. This might include, for example, the accumulation of wealth and collection of property in response to the instinct to attract a mate and secure a comfortable living environment. There is an implication however, that an evolved, instinctive response might be elicited by aesthetic stimuli. It might be assumed therefore, that humans have an innate ability (at least to some extent) to determine what is good or bad in response to visual stimuli, regardless of what they have learned or been influenced by as a result of their culture, environment and society.

Joseph LeDoux (1996) sought to explain the processing of emotional information. Physiologically speaking, emotions are considered to be a manifestation of the electrical impulses created in the brain by conscious and subconscious thought. The limbic system is the area of the brain most affected by emotion, with the amygdala playing a particularly important role in regulating emotion. Conditions such as autism, depression, bi-polar disorder and phobias are thought to be linked to abnormal amygdala function, sufferers of which tend to exhibit certain emotional difficulties or dysfunction. Emotional stimuli are sent via two routes: A fast, subcortical route and a slower cortical route. The direct route allows for quick, instinctive responses to stimuli while the indirect cortical route provides awareness so that emotional responses can be controlled and, if necessary, overridden. A diagram illustrating an interpretation of the relationship between these two routes is shown in fig 2.1.

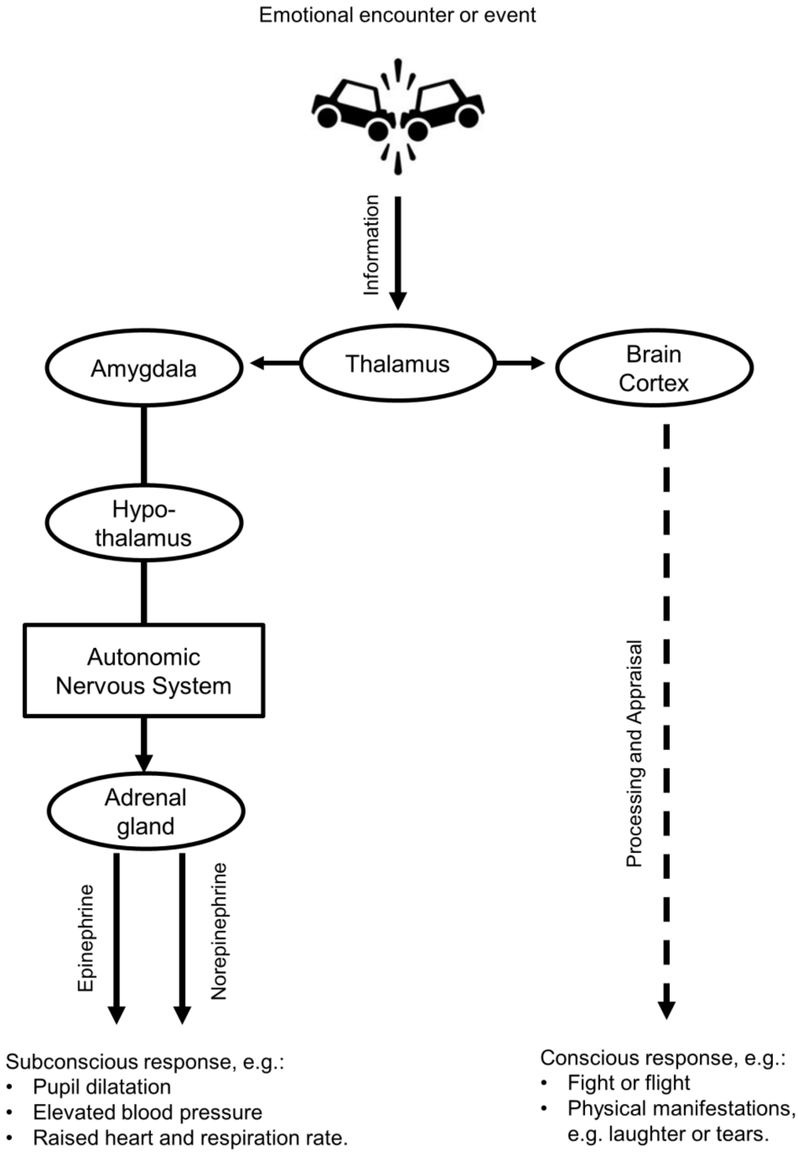


Fig.2.1- The physiology of an emotional response

In his book ‘Emotional Design’, Donald Norman (2004) describes three levels of processing to which he refers to as visceral, behavioural and reflective. The visceral (or reactive) level he describes is responsible for the initial instinctive reactions that occur during a new physical or visual encounter. It rapidly makes assessments as to whether something is good or bad and forms the first stage in affective processing. This resembles the sub-cortical route described by LeDoux (1996). It is very fast but can be superseded and moderated by conscious thought. In terms of emotions experienced during first-contact with products, the visceral level could be considered a significant factor in setting the context for subsequent emotional responses. Particularly if a positive first impression sets the tone for subsequent emotions processed at the behavioural level.

Norman refers to the second stage in emotional processing as the behavioural level. This is concerned with the majority of human activity. It is at this level that conscious decisions are made and represents LeDoux’s cortical route. The behavioural level provides a more detailed appraisal of the here and now. It can influence judgements made at the visceral level. However it can subsequently be influenced by the third, reflective level.

Conscious thought can overcome an initial reaction but it can also be affected by experience and memories. It is at the reflective level that experiences are revisited after they have happened, and while reflection is not linked directly to the senses, it has a significant influence on how a similar experience might be dealt with in the future. The Hippocampus is the part of the limbic system that plays a key role in forming new memories and in converting them from short-term to long-term memories (Ciccarelli & White, 2012). The reflective level (i.e. associated with memories) influences the way we experience emotions in response to current or anticipated events. It is through this mechanism that similar, past experiences can be recalled in the present. With regards to product design, this might be in the form of a product appraisal, comparison or selection, where a pleasant or unpleasant association is recalled through connotation. In this respect, it could be difficult to predict one’s specific emotional response to a design as it will be influenced by individual circumstances. All three levels described here can be seen to play a part in influencing emotions to varying degrees during an encounter with a product for the first time or on subsequent occasions (fig. 2.2).

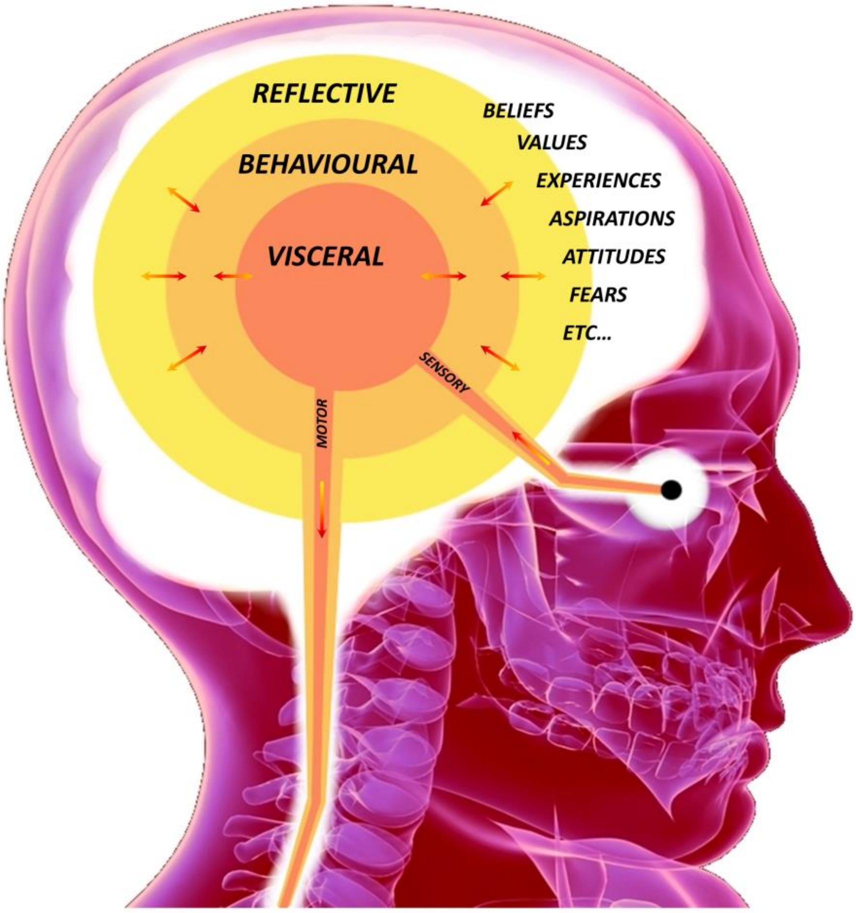


Fig 2.2 – A Diagrammatic representation of Norman's three levels of emotional processing (Author)

First impressions have been shown to be very powerful in a wide range of contexts. Strong visual impact in websites has been found to draw attention away from usability problems (Lindgaard, et al., 2006), suggesting that visual appeal is detected first and potentially influencing users' subsequent experiences. This lasting first impression can carry over to the evaluation of other product attributes and is sometimes referred to as a 'halo effect'. In human decision-making this phenomenon is typically referred to as a ‘confirmation bias’, occurring when participants search exclusively for evidence that supports their initial appraisal rather than seeking to determine otherwise (Lindgaard, et al., 2006). So a highly positive first impression can lead someone to overlook (to an extent) subsequent negative experiences should they occur. Vice versa, a negative first impression is likely to contribute to or support one’s view that the design is somehow inferior and that the product fails to provide a positive user experience (Campbell & Pisterman, 1996).

Ratner (2000) identifies emotions as having the following characteristics that he says originate in and reflect cultural activities and concepts:

(1) Quality, (2) Intensity, (3) Behavioural expression, (4) the manner in which they are managed or resolved, and (5) Organisation -- wherein any emotion is more closely akin to or divergent from others.

The particular emotion that one may perceive in response to a given situation will also depend on one’s understanding of the elements at play within that situation. These include: the immediate stimulus or cause; the needs of the individual; the social context; the consequences of the situation or other specific characteristics associated with it, in addition to the positive or negative value one might assign to the emotional response. It is therefore unlikely that someone would experience a violent or angry response to a product’s design unless it was the designer’s intention to be deliberately provocative or controversial.

Schachter and Singer proposed that people’s experience of emotion depends on physiological arousal and cognitive interpretation of that arousal (Ciccarelli & White, 2012). They concurred with the earlier James-Lange theory, that people infer emotions from physiological arousal. But they went on to determine that similar patterns of physiological arousal can give rise to different emotional responses. The Canon-Bard theory of emotions differs slightly again, in that it suggests the experience of emotion happens at the *same time* that physiological arousal happens, rather than following it (Ciccarelli & White, 2012). In this case, the brain gets a message that causes the experience of emotion at the same time that the autonomic nervous system gets a message that causes physiological arousal, hence neither one causes the other. Thus, when people perceive physiological symptoms of arousal, they look for an environmental explanation of this arousal. This implies that the type of emotion a person perceives depends on what they find in their environment. E.g. The subject of Marcel Duchamp's *Fountain* (a white porcelain urinal) when perceived in an art gallery has been known to generate significant surprise and controversy. However, were the original Bedfordshire model urinal to be perceived in its initially intended environment, it would likely be considered ordinary and of little significance. Richard Lazarus took this further in his cognitive meditational theory (Ciccarelli & White, 2012) by suggesting that people's experiences of emotions can depend on the way they appraise or evaluate events. E.g. A motorbike can elicit a myriad of emotional responses including desire, exhilaration and fear. These emotions can be experienced in the same individual or between different individuals, whether they are riding the motorbike or just observing it.

2.3 Design for Emotion

A relatively new discipline within the fields of design and engineering (ENGAGE, 2005), design for emotion is based on the basic premise that people acquire greater value and satisfaction from products that meet their emotional requirements as well as their utilitarian needs. Hassenzahl (2004) refers to this as 'goodness' which he says depends on both pragmatic (e.g. perceived usability) and hedonic attributes. He draws a distinction between this and 'beauty', which he suggests typically implies an outstanding quality associated with predominantly hedonic attributes (i.e. very visually attractive). The implication is that products that successfully fulfil a variety of emotional needs are likely to be more commercially successful as a result.

In 1999, the department of Industrial Design at Delft University of Technology held the first Design and Emotion conference. The Design and Emotion Society grew out of that event and continued to hold international conferences on a biennial basis until 2017, attracting significant interest from across the design community. In 2005, the ENGAGE report on Engineering Emotional Design was published in an effort to compile and characterise the various methods, terms, tools and techniques associated with this fledgling field. Since then, a significant body of work has been published in the area and the terms design and emotion are becoming more established within the design community. There is now a growing awareness of the impact and implications that our emotions can have on the way we select, purchase, interact with and discard the things that we own. Emotional design strives to move these issues towards the top of the design agenda in an effort to improve our interaction and ownership experiences.

Product design can evoke layered emotional responses and it is possible to design products that target specific types of emotion. The following set of 25 emotions (in alphabetical order), were found to be regularly experienced in response to consumer products (Desmet, 2004):

admiration; alarmed; amazement; amusement; astonishment; avaricious; boredom; contempt; curiosity; desire; disappointment; disgust; dissatisfaction; eagerness; fascination; indignation; inspiration; irritation; joyful; pleasant surprise; satisfaction; softened; stimulation; unpleasant surprise; yearn.

Not all conceivable emotional responses to products appear in this list, e.g. *fear*. To design a product that evokes fear might seem at odds with traditional commercial objectives. Who would want to buy a product that evokes fear? However, in the right context such an emotional response could still be considered desirable. For example, the prospect that certain products such as guns, knives or dangerous tools might elicit fear could be perceived to impart the product's owner with a sense of power and satisfaction. In this sense, the knowledge that a product's design can elicit such an emotional response may be pleasurable to that individual. Tiger (1992) proposes four pleasures that he says relate to the way in which we perceive design. These are listed as follows:

i) Physio-pleasure , e.g. Design to promote physical comfort during use;

ii) Socio-pleasure, e.g. Design or brand that promotes pride of ownership and esteem amongst one's peers;
iii) Ideo-pleasure, e.g. Design or brand that reflects one's principles and ideology;
iv) Psycho-pleasure, e.g. Design that promotes an enjoyable or satisfying mental interaction.

Considering Norman's (2004) aforementioned model, it is conceivable that all these pleasures could be experienced both at the behavioural level as well as at the reflective level, when the product in question might not even be present. The idea of the product is sufficient to elicit an emotional response. That idea could be prompted by a memory or pictorial representation. Thanks to modern CAD technology it is possible to create highly convincing design representations before a physical product even exists.

McDonagh et al (2004) suggest that designers w*ant to design experiences and generate pleasurable or exciting sensations*. It is generally accepted that if a design is capable of evoking the right emotional response then that design should be more popular and achieve greater commercial success. Since people experience product design in different ways and at different times, it is difficult to determine precisely how any one individual will respond emotionally to a particular design concept. Their responses to a product may depend on all manner of variables, including:

- Medium of interaction, e.g. photo, video, audio description, etc.
- Purpose of interaction, e.g. pure chance, gift, advert, intended purchase, business or personal purpose etc.
- Type of interaction, e.g. passive/active, direct/indirect etc.
- Familiarity of interaction, e.g. first, infrequent, regular, customer/owner/user etc.

The emotional response that an individual experiences in relation to a product will also depend on the degree to which the product's design meets the expectations and aspirations of the individual. In design and engineering terms, this is usually determined by whether the designer or design team were successful in optimising a particular set of parameters. For consumers, this aspect of design has a significant bearing on the way products elicit different emotions and subsequently how people relate to the products they have around them. Such behaviour can generally be classified according to three product properties; aesthetic, functional and social (Crozier, 1994). Fig 2.3. illustrates the relationship between product properties and familiarity.

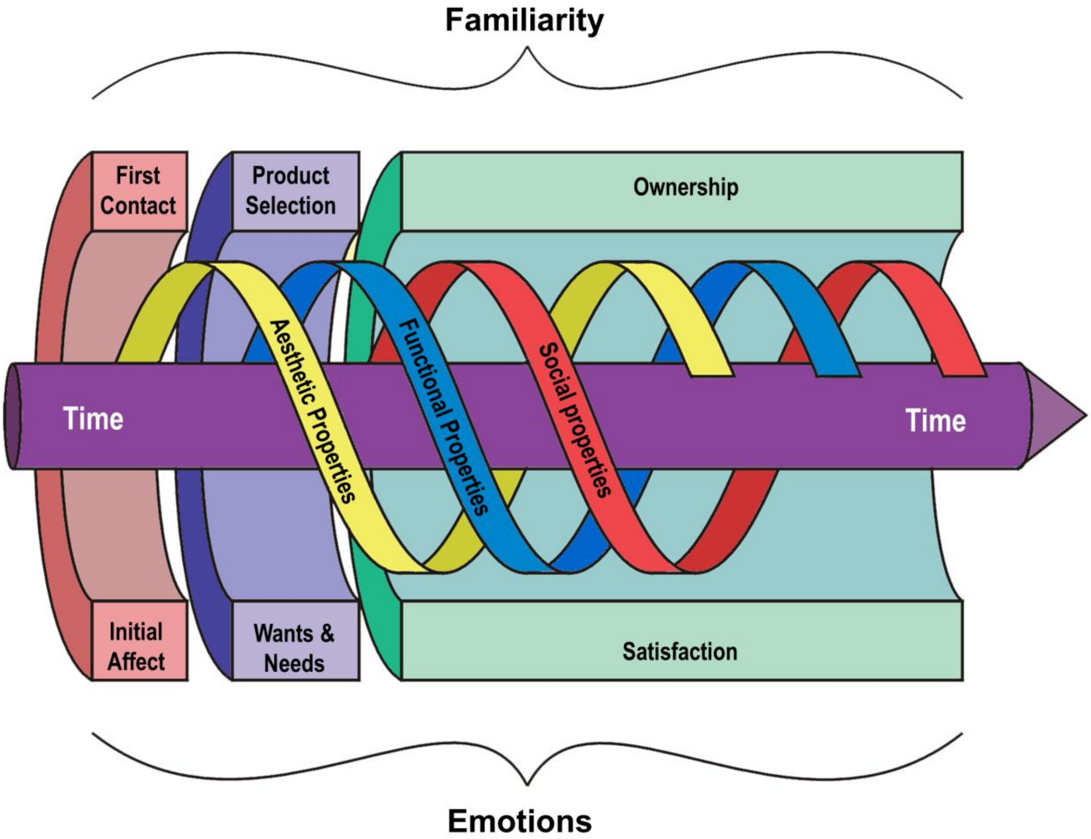


Fig. 2.3 – Emotions, Familiarity and Product Properties

People can become emotionally attached to products as familiarity develops over time. Govers and Mugge (2004) describe how this relationship can exist, even after a product becomes damaged or obsolete and serves no useful function. Design for emotion (or *emotional design*) then, is a necessarily multifaceted discipline due to the range of influences by which people can be affected. To be able to design for emotions, it is important to have some understanding of how emotions are affected by products and the role that those emotions play. Furthermore, Jordan (2002) suggests that for a product to evoke positive emotions, it should engage with people on three levels:

i) fitness for purpose/ability to perform the task;

ii) emotions associated with the product and task(s);

iii) the aspirational qualities associated with the product.

Emotional responses could be regarded by some as subjective, even inconsistent factors upon which to base design decisions. However, objective thinking often involves some degree of emotion (e.g. a passion for speed and efficiency) and while emotions may be inconsistent, the external factors that influence them are more predictable. According to Epstein, emotions can play a central role in thinking, knowing and processing information (Epstein, 1994), with reality being perceived through a cross-coupled affective (intuitive)/cognitive (analytical) system. In other words, emotions can have an effect on thinking and thinking can affect our emotions. Minsky (2006) suggests that an emotional state is just another style of thinking, and counters this against *our traditional idea is that there is something called "thinking" and that it is contaminated, modulated or affected by emotions.* There is significant emotional processing associated with products and product design, but the types of emotions, their occurrence and associations can be highly varied and complex. Emotional diversity across cultural boundaries (e.g. religion, gender, professions etc.) must therefore be taken into consideration during the design process (Khalid & Helander, 2006).

According to Spillers (2004), people use artefacts (mental and/or physical) to extend cognitive abilities and solve problems during task completion, stating that…*it is necessary to understand the role of cognitive artefacts and how emotions play the role of "affective artefacts" in the interaction design process,* and *"affective artefacts" represent or elicit emotions and assist product interaction and user cognition during the product appraisal process*. Designers can gain valuable insight by identifying the role that artefacts play during product interaction and appraisal. Particularly as the feelings of satisfaction or disappointment may follow an emotional change of state depending on whether the interaction resulted in success or failure.

Appraisal theory (Desmet, 2002; Lazaraus, 1991) goes some way to explain how products elicit emotions through their appearance. According to this theory, when a person makes a conscious or sub-conscious assessment of a product's effect on their well-being, product appraisals are made in terms of the product's sensory appeal, its novelty, its association with the person's goals and its function. In cognitive psychology, an appraisal is usually a quick, non-verbal evaluation of a situation with respect to one's well-being (Friida, 1986; Lazaraus, 1991; Demir, et al., 2009). Further to this, appraisals can often be differentiated by two approaches: thematic (summary statements reflecting the overall personal meaning of a situation); and componential (described in terms of several questions, each focussing on a different aspect of the situation) (Demir, et al., 2009). While these approaches differ, they are not mutually exclusive and offer a relationship between a person's evaluation of a product and the associated emotions they experience, (i.e. a particular emotion will often arise from any given appraisal pattern). Distinct appraisal patterns can give rise to particular emotions and this provides a useful starting point when designing for emotions, although the challenge of identifying appraisal components and making them tangible enough to be of use to designers must first be met. Desmet (2002) goes on to derive a model of product emotions, which he based on appraisal theory. This model consists of three elements:

i) Appraisal: An evaluation event of whether a particular stimulus is significant to one's well-being.
ii) Concern: One's personal preference for certain conditions or qualities.
iii) Stimulus: The aesthetic qualities eliciting an emotional response.

Product properties can be categorised into two schemes, each consisting of three references (Muller & Pasman, 1996; Lenau & Boelskifte, 2005); the utilitarian (sensory, instinctive and inherent) and the communicative (perceptive, learned response and reflective). The references within each scheme can relate to different aesthetic qualities. For example, sensory can relate to geometrical elements; shapes, lines and textures. Instinctive can relate to physical characteristics such as features facilitating the operation of a product. Inherent references relate to the basic nature of a product, e.g. masculine and feminine. The perceptive reference relates to social aspects such as stereotypes and groups. The learned response reference relates to intrinsic qualities such as product quality, value and newness. Finally, the reflective reference relates to qualities that the user aspires to, such as modernity and fashion.

It has been shown that the emotional content of a product interaction is influenced both by the use/ownership of the product itself and knowledge of the product alternatives (Chitturi, 2009; Dhar & Wertenbroch, 2000). Ultimately, an effective design will be judged by whether it *…generates a desirable consumption experience and favourably influences subsequent consumer behaviour* (Chitturi, 2009; Desmet & Hekkert, 2007). It is important that designers understand the nature of the consumption experience and the positive and negative emotions that may arise from it. To this end, it is perhaps convenient to regard products on their hedonic (e.g. aesthetic) and utilitarian (e.g. functional) merits. Particularly so when it has been found that attributes offering hedonic benefits evoke more negative emotions than those offering utilitarian benefits when they fail to provide the expected consumption experience (Chitturi, 2009).

2.4 Affective Methods and Approaches in Design

'Kansei Engineering' was developed initially by Mitsuo Nagamachi in the mid 1970's (Nagamachi, 2010), and was one of the first formally recognised approaches to design for emotion. A popular exemplar of the Kansei engineering approach is the Eunos Roadster (Mazda MX5) car that sold over 400,000 units in its first iteration between 1989 and 1997. That many of those early examples are still seen on the roads some twenty five years later provides some testament to the method's success in meeting the customer's emotional needs. Kansei can be regarded as a 'passive mental process' affected by external factors such as an artefact, environment or situation. The term Kansei did not exist in Japanese psychology until relatively recently and does not readily translate into other languages (Schütte, 2005). It incorporates the meaning of the words: sensitivity, sense, sensibility, feeling, aesthetics, emotion, affection and intuition and can be loosely defined as:

Kansei: Sensitivity of a sensory organ where sensation or perception takes place in answer to stimuli from the external world.

Nagamachi defines the Kansei discipline as:

A consumer orientated technology for product development based on Ergonomics and Computer Science (Nagamachi, 1995).

He goes on to describe Kansei as having three focal points:

1. How to accurately understand customer Kansei.
2. How to reflect and translate Kansei understanding into product design.
3. How to create a system and organisation for Kansei orientated design.

Kansei Engineering links customer's emotional responses to specific attributes of a product in order to determine the optimum emotional response. The approach systematically determines the effect of a product by using words relating to feelings within a specific product domain. People can verbally distinguish between discreet emotional responses that result from product interactions (Desmet, 2004) including the relevant causes and effects. Kansei (Affective) engineering is one of the earliest recognised methods developed specifically for designing products that meet people’s emotional needs.

The following ingredients of KANSEI were compiled following completion of a questionnaire by twenty nine researchers on the Evaluation of KANSEI Special Project of the University of Tsukuba (Overbeeke & Hekkert, 1999):

1. Subjective and indescribable functions.

2. In addition to inherited nature, cognitive expression based on knowledge and experience.

3. Interaction between intuition and intellectual activity.

4. The ability of intuitive response towards distinction of objective world.

5. The image creating function of the mind.

Participants undertaking a Kansei evaluation experiment use a semantic differential scale (Osgood, et al., 1957) to evaluate product attributes in relation to strength of feeling. Kansei words are carefully selected to ensure the semantic (meaning) and pragmatic (contextual) appropriateness to the desired product domain or context. Semiotics plays a key role here as the words selected may have particular symbolic significance. Further to this, semiotics identifies a clear link between the verbal signification of an object, its visual representation and the object itself. Considerable research has also been undertaken elsewhere to identify a typology of emotions attributable to the way people relate to products (Desmet, 2004), demonstrating the significance of semantics in the design process. In Kansei Engineering, participants' emotions are captured in relation to a broad range of sample designs from within the target product domain. Data from this activity is analysed statistically and used to inform designers on how those attributes should be provided in order to gain optimum affect. The power of this approach stems from the broad sample size and the specialist expertise provided by the 'Kansei Engineer', who's responsibility it is to oversee the activity. Robust statistics add credibility to the process while the Kansei engineer's experience ensures that data is interpreted appropriately (Schütte, 2005).

The aforementioned field of semiotics (the study of signs) provides an insight into how people read objects. It also offers an explanation for how our perceptions are influenced (and how emotional responses can be elicited) by meanings represented through symbolism embodied within form. The Swiss semiotician; Ferdinand de Saussure, demonstrated that meaning is signified as a result of aspects of signs known as signifiers (Cobley & Jansz, 1999). Since human perception is dominated by vision (Xue & Yen, 2007) and art and design are rich in visual signifiers, there is a high potential for the communication of meanings through those media.

Saussure defined a sign as being composed of:

A Sign = ↑ <u>The Signified – the concept it represents</u> ↓
A Signifier – the form that the sign takes

Jacques Lacan on the other hand, argued that the signifier belonged on the top and the signified below to show how the signified inevitably "slips beneath the signifier and refuses definition" (Hjelm, 2002):

Signifier - the expression, The FORM, the aesthetics, Objective – outer world

signified - the content, The CONCEPT, what it stands for, Subjective – inner world

Either way, these both illustrate the relationship that exists between object and meaning. That an object can express a meaning and the meaning can be expressed through an object is of particular significance in design for emotion, where a designer may attempt to communicate one or more attributes or connotations to elicit an emotional response. Product semantics, defined as 'the study of symbolic qualities of man-made shapes, in the cognitive and social context of their use' (Krippendorff & Butter, 1984; Demirbilek & Sener, 2003) is concerned with the relationship between users and products in the functional and social contexts in which they are found. Manufactured products communicate designers' intentions through their form and CMF (Colour, Materials and Finish). Those attributes, carefully selected and manipulated by the designer, form part of a language structure and, just like words, can carry meanings (Demirbilek & Sener, 2003). The designer's goal is to load the product with signs, which later can be decoded by the user. Product semiotics helps to explain why a product is interpreted as it is (e.g., expressing 'aggression'), but not what emotions it will evoke in the user. Depending on their experiences, people associate different emotions with products. Tools, for example, may bring joy to one person but may be associated with fear (of causing an accident) for another. Furthermore, the perception of product properties is likely to be influenced by the media or context of representation. For example, products represented in pictures can be placed in certain contexts, something that advertisers have exploited to great effect. The responses of individuals perceiving those pictures will be influenced by the way an image is composed and the way the product is represented within that image (Hiort af Ornas & Karlsson, 2004).

'Design language' is a term sometimes used to describe a particular design philosophy or product family (Eves & Hewitt, 2009). This, amongst other things, helps designers to distinguish one product design (or group of designs) from its counterparts. The design features in question may be subtle or clearly evident, perhaps most plainly so in the automotive industry. Here manufacturers will often produce several different vehicle models within a range, each being clearly distinguishable and yet linked with its 'siblings' through some aesthetic design feature or motif (fig 2.4). In these instances, the design language will be used, for example, to:

- Define the vehicle's family and to set them apart from those of its competitors.
- Link new products with popular models from the past to suggest heritage.
- Suggest aspects of the product's function to facilitate more intuitive user interaction.
- Suggest product attributes and meaning (such as power or speed) to make the vehicle more appealing to the target market.

'Verbal language' and adjectives in particular, can be used to describe a product's typology, function(s), features, materials, colour and so on, in considerable detail. The semiotics of design language and the way it relates to aesthetics is significant. Design language is rich in verbal and visual signifiers. The application of semiotics to design can have a profound effect on the way a person relates to the aforementioned product attributes (Eves & Hewitt, 2009).

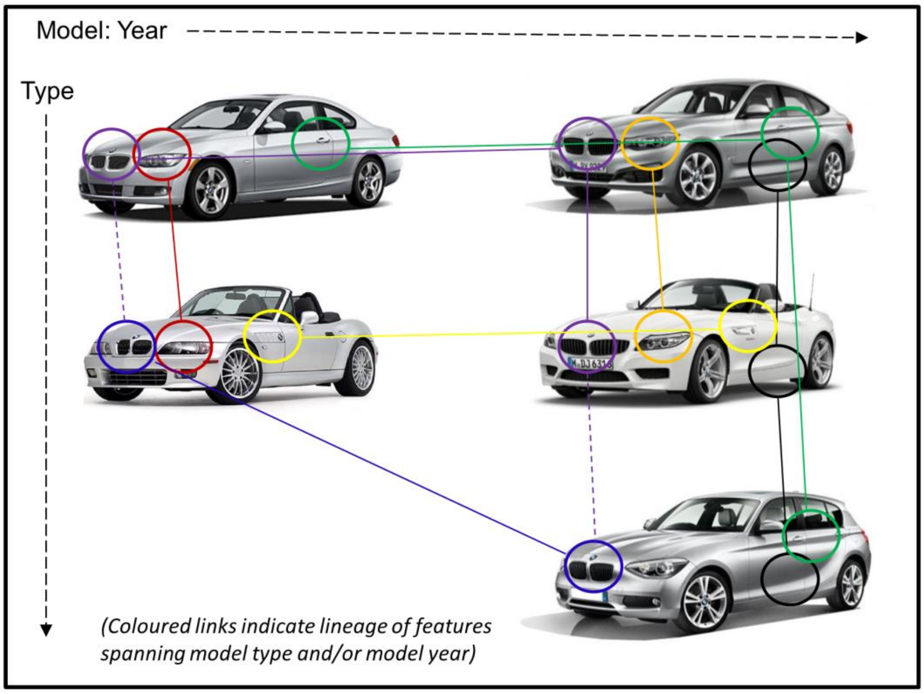


Fig. 2.4 - Design Language in Automotive Design

Comparison can be seen to exist between a person's self-concept and their perception of a product (Govers & Mugge, 2004). Consumers prefer products that align with their self-concept because they experience high self-congruence with respect to those products. This phenomenon is derived from the paradigms we create and our need to express a consistent, positive view of ourselves. Products can provide a medium by which individuals can outwardly express their self-concept (Sirgy, 1982). For example, by owning a sports car, one may hope to project an image of being fun-loving, free and exciting. Consumers prefer self-congruent brands and this increased level of product-personality congruence will usually result in a higher level of product attachment than those products that appear to be incongruent (Aaker, 1999). Designers can exploit their understanding of semiotics, semantics, design language to ensure that a product's aesthetic maps successfully to a customer's self-concept.

2.5 Computers in Design and Emotion

The term 'Computer Aided Design' (CAD) used here refers to software intended for the direct manipulation of 3D geometry. In the fields of design and engineering, the capabilities of CAD and its breadth of application are constantly evolving. Séquin (2005) describes how the role of the computer goes much further than merely a digital replacement for traditional drafting and visualisation tools. He notes that advances in computer technology have largely been responsible for facilitating fully interactive CAD tools, citing the advances in hardware and software approaches (e.g. subdivision surfaces) that combine to reduce computation time and, subsequently, permit real-time manipulation of geometry. In the context of design for emotion, such CAD tools can specifically help designers impart their products with particular emotional characteristics, according to their design brief. The scope and nature of such a tool may vary considerably, depending on:

- The type of CAD software being used (e.g. surface or solid modeller) and the associated modelling process.

- The point in the design process at which the tool is employed (e.g. a CAD tool that is useful during the conceptual design phase may have limited application later in the design process, and vice versa).
- The breadth of available product domains, which adds significant diversity and therefore complexity to any generic CAD tool.

As discussed previously in this chapter, designers can exploit the link between form, language and emotions. It would therefore be beneficial for a CAD tool (for the purposes of emotional design) to fit that model. To augment design concepts based on language, it is necessary to employ a rule based system for geometric manipulation. Stiny and Gips (1980) proposed one such system in ‘shape grammars’, which is a production system for generating two or three dimensional geometry. A shape grammar consists of a shape rule that determines how a shape (or part thereof) is transformed (e.g. rotated, reflected or scaled). By defining a start rule, a transformation rule and a termination rule a shape grammar can be created. Shape grammars have been used successfully to capture and reproduce brand identity in new product designs, such as Harley Davidson motorcycles (Boatwright & Cagan, 2010) and Buick automobiles (McCormack & Cagan, 2004) and provide a means of emulating particular design intentions through their application.

It is conceivable that shape grammar algorithms could be applied to manipulate geometry by mapping words or verbal phrases onto them. In this instance, the words used could act as a) a trigger to activate an individual shape grammar, and/or b) define a string of parameters or set of algorithms that combine to produce an overall effect. The choice of words themselves can be arbitrary but the mechanism that interprets them and converts the instructions into actions would need an appropriate context and parametric constraints. The problem here is that a single word can mean different things in different contexts. Not only might the meaning of the word itself be open to semantic interpretation, but also the rationale for that word’s application as a geometric driving force. Without some sort of human or artificial intelligence in the feedback loop, further iterations might merely increase the intensity of the initial effect.

The FIORES-II project (Character Preservation and Modelling in Aesthetic and Engineering Design) ran from April 2000 to March 2003. It was aimed at creating innovative CAD tools capable of capturing and preserving product aesthetic character while helping designers meet their objective of eliciting emotional responses. The project was intended to improve the working procedures and CAD tools for modelling product form, by providing CAD tools capable of handling both styling and engineering requirements simultaneously (Giannini & Monti, 2002). The need to maintain integrity of both engineering parameters and aesthetic character was acknowledged and the intention was to employ artificial intelligence techniques to provide a structure between styling character and shape geometry. Its general objectives were to develop:

- A vocabulary for aesthetic design;
- A mapping between character and aesthetic properties;
- Methods for the extraction of aesthetic shape properties;
- Methods to optimise the design with respect to aesthetic and geometric engineering requirements.

The proposed CAD tool was primarily language based, using verbal modifiers to manipulate geometric entities. These modifiers provided fixed semantics to link aesthetic character with geometric elements. For this purpose, two groups of terms were categorised:

- Marketing language: (described as a language of trends) used to communicate emotional character.
- Designer language: (described as a language of trades) used to communicate design intent.

The FIORES II team employed a ‘traditional’ UI to reduce the time needed for training and familiarisation. The impact of the UI’s design on the designer’s experience should not be underestimated. A good user interface can be conducive to a more liberating and creative experience, and yet often the UI of a CAD tool is its weakest link (Séquin, 2005). The additional freedom provided by the FIORES-II CAD tool resulted in a more user-friendly and creative user environment. Claimed productivity gains of as much as 99% were reported as a result of time savings over traditional feature creation methods. The CAD tool was tested with industrial partners and it was found that the modifier approach worked well. However, they found that ambiguities remained between the marketing and design language and that translating designers' subjective perceptions of form into mathematical formulae posed significant challenges. For a CAD tool to be able to respond to aesthetic adjectives, a consistent design language is paramount. This would require the identification of direct relationships between an object's geometric elements and its aesthetic character, ideally, mapping the parametric values to the intention. However, people often perceive objects by comparing them to what they already know. Since this can depend on culture and experience, an absolute definition of an aesthetic character can be very difficult to achieve (Giannini & Monti, 2002).

The language and definitions used to describe aesthetic aspects and emotional responses can play a crucial role in mapping the designer's inputs with the desired outputs. Hsiao and Wang (1998) proposed a semantic transformation method for form in product design. Their model used a database of product shapes and image words, built using the membership functions of a fuzzy set. The relationships between the abstract image words and the shape regulating rules contributed to the embodiment of form via a computer program capable of manipulating B-spline CAD data. Basic three dimensional models of a product could be constructed, starting with an image word for describing the required product.

There has been considerable research into CAD tools for design and emotion where the emphasis is on mathematical approaches to solving geometric problems. However, in his PhD thesis entitled Designing Emotions, Pieter Desmet proposed two novel and alternative design tools. One tool: PrEmo (Product Emotion Measurement instrument), is a user-centred tool for evaluating product related emotional responses to product appearance. This tool was initially developed in response to a need to assist automotive designers in *manipulating the emotional impact of their designs* (Desmet, 2002). The PrEmo evaluation software measures fourteen product relevant emotional responses non-verbally, using cartoon characters. The key to this self-report tool's broad appeal is that it is can be applied to any genre of product and it provides an intuitive interface which requires very little interpretation (by the individual) when recording an emotional response. Used within the design process, PrEmo assists designers by providing them with a feedback mechanism for their proposed design concepts, rather than a means of creating the concepts themselves. The PrEmo tool has since been developed commercially with some success (Susagroup, 2014) to provide integrated data collection and analysis tools.

Desmet's second tool, the 'Product and Emotion Navigator' was created to support designers throughout the design process by providing them with stimuli and inspiration during concept generation. This tool was intended to familiarise designers with his (aforementioned) model of product emotions. The tool was essentially a computer database of eliciting conditions matched to product examples. It did not provide design rules or specific guidance for design. Instead, the Product and Emotion Navigator assisted in the analysis of existing products (using the aforementioned 'model of product emotions'), in the hope that this would offer insight that designers could subsequently incorporate into their own new designs. Both tools operate within a computer environment and yet neither are specifically 'CAD' tools in the traditional sense, because neither is actually capable of creating design geometry. However, their capabilities and emphasis are relevant to this research as they are indicative of how design for emotion can be applied in different ways and at different stages in the design process.

2.6 Randomness within the Design Process

The process of developing a new product is often punctuated by a series of decisions, made to meet the needs and expectations of the various stakeholders (e.g. customer and manufacturer). A designer will normally adopt a process that enables them to expedite a design project most effectively. There are several well documented models that attempt to define the design process (Pugh, 1991; Acar, 1996; French, 1999; Pahl & Beitz, 2007) (see Appendix A). Most follow a fairly similar and logical sequence and are iterative in nature. All provide a framework within which the design of a new product can be described. These models do not provide guidance on how to be creative or how to design for emotions. However, there are invariably key points in the design process where it is beneficial to be able to do so.

The early stages of the design process tend to focus on information gathering and research. Having accumulated sufficient knowledge of the task in hand, the designer normally goes about generating a broad range of alternative design possibilities, known as concepts. These encapsulate all that the designer has learnt through their research and represent how they might go about resolving all the issues, including who will buy it, how and where they will use it and so on. Typically, concepts should be divergent and differ in a variety of ways in order to explore a broad spectrum of alternative possibilities (Hurst, 1999). It is at this point that a designer's creativity is tested most. The designer will likely consider many factors and produce concepts that emphasise different aspects of the solution, including the way the product functions, how much it will cost and the way it looks and feels. Many new concepts are created, so a means of selecting the most suitable concept is employed. That concept is often taken forward into a more detailed phase of design where precise dimensional and physical aspects are determined.

A thorough concept creation phase can employ a combination of design methods intended to stimulate creativity and problem solving ability. These approaches often involve lateral thinking techniques as opposed to vertical thinking (De Bono,1990; Hurst, 1999). Vertical thinking, being the domain of sequential logic, tends to result in the same type of result time after time. Lateral thinking provides alternative ways of considering a problem, and its application helps to find radically new solutions. Creativity in the design process is often characterised by the occurrence of a creative event or 'leap' (Dorst, 2001), but even lateral thinking provides no guarantee that such an event will occur. This would seem to imply that there is sometimes an element of chance involved in making significant creative steps. Indeed, De Bono (1990) himself suggests that *with vertical thinking one concentrates and excludes what is irrelevant, with lateral thinking one welcomes chance intrusions*.

Chance and randomness are closely related and more often than not may even be considered synonymous, although according to Eagle (2016) it is incorrect to consider them as the same. For the purposes of this PhD, randomness will be considered as the process by which chance occurrences are created. In other words, random variables act to remove patterns that would otherwise lead to predictability, so that unpredictable results appear ‘as if by chance’. It is its ability to break patterns that makes randomness useful in practical, lateral thinking applications (De Bono, 1990). However, the degree of randomness applied to geometric form in product design should be constrained, not least to preserve a product’s functional integrity. While highly novel and unusual designs are likely to elicit the strongest emotional responses, they may not always be positive ones. Veryzer and Hutchinson (2014) and Hekkert et al (2003) claim that people respond most favourably to objects that demonstrate high levels of unity and typicality. In other words, that a design is clearly representative of a particular product type and that there is congruency between elements within that design.

Randomness has been found to be a key element in generative design applications for product design (Graham, et al., 2001; McCormack, et al., 2004; Krish, 2011). Generative design involves the application of a computer program to generate multiple design iterations. Generative design typically uses a set of rules (usually in the form of an algorithm) to generate concepts within minimal and maximal constraints. The role of the random element is to reduce repetition and stimulate concept diversity. This aspect of generative design provides designers with the ability to explore design ideas that they would otherwise not have envisaged. As such, randomness also plays an important part in providing creative inspiration for subsequent design iterations and refinements (Graham, 2012). It is preferable in almost all cases, for the designer to maintain ultimate control over the evolution of concepts to ensure functional and aesthetic integrity are preserved.

For designers, unpredictability represents an opportunity to unlock latent possibilities during design concept generation. In many cultures the unpredictability afforded by a coin toss or a throw of the dice means it also provides a mechanism for an unbiased decision making process (Bennet, 1999). The element of unpredictability that chance provides facilitates many gambling activities (e.g. roulette) and has been employed in toys (e.g. Uno extreme) and media devices (e.g. iPod shuffle) to add surprise, suspense and entertainment value. It is apparent therefore that the act of play provides a practical link between chance, surprise and entertainment.

Appraisal theory suggests that an emotional response to a product design is a result of one's interpretation of perceivable stimuli within the environment. Where a product's design is atypical, an evaluation is made to determine whether that design is superior or inferior to the norm. Ludden et al (2006) recognised that positive surprise can be beneficial in product design, and proposed a two-stage model to help designers better understand the relationship between surprise and emotion. In the first stage, an individual's appraisal of an unexpected encounter leads to a surprise response. In the second phase, the surprise is evaluated further depending on the particular values held by that individual. The residing emotional response may be one of amusement or disappointment (for example). Where amusement or interest can be elicited, the designer has the opportunity to exploit the surprise to their advantage. Conversely, the implications of an unpleasant surprise need to be understood by the designer to ensure that negative connotations are avoided.

Pleasure, surprise and anticipation are recognisable elements of play (Eberle, 2014) lending support to the idea that play is an important, even integral, part of the creative process (Norman, 2004). Play in design is recognised as having significance, particularly in the early problem solving stages of the design process. Play is a natural learning and problem solving mechanism. Enjoyment provides motivation meaning that persistence in solving the problem is increased. Norman (2004) describes the importance of a relaxed, good mood when creative thinking is required for activities such as brainstorming. He also discusses the associated benefits of happiness and how dopamine is released as a result of positive valence which can result in enhanced breadth-first problem solving ability (Norman, 2003).

Aleatoricism (of or pertaining to luck or chance (Farlex, 2016)) is an approach that a number of prominent artists have adopted (Leong, et al., 2006). The word 'Aleatory' comes from the Latin for dice, *alea* and simply implies that a random process is used to make decisions. Used as a creative tool for generating breadth and variety in their work, it can enrich the experience of the beholder. Randomness has been used by the avant-garde composers Pierre Boulez and John Cage to create unforeseen sounds, sequences and musical procedures. Boulez adopted an approach that he called 'controlled chance' in some of his compositions, including 'Alea' which was named after the technique itself (Boulez, et al., 1964). John Cage studied Zen philosophy and derived a computerised musical composition tool from a classic Chinese textbook 'I Ching'. This number based book of wisdom was traditionally used to identify order in chance events. He used it to create innovative and unexpected sounds in pieces such as 'Music for Piano', that are unconstrained by the composer's conscious determination (Kostelanetz, 2003). One of Cage's most controversial pieces was titled *4'33"* (Hemmings, 2005). This piece consists of no musical arrangement and is silent, meaning the random ambient sounds created by the musician and listeners themselves become part of the composition. Subsequent performances are always perceived slightly differently by the audience even when watching or listening to a recording.

Smith (2016) lists other notable artists that have used aleatoric techniques in the creation of their work, including:

- Leonardo da Vinci took inspiration from blotches on walls as a means of initiating artistic ideas,
- Tristan Tzara, who created poetry by randomly selecting and reconfiguring sentences from dictionaries and newspapers,
- Jean Arp, who would create collages by dropping small pieces of paper onto a larger piece before fixing them where they fell, and who developed a technique known as 'automatic drawing' where, by allowing his pen to randomly meander over sheets of paper, he hoped that he might free his repressed subconscious. This approach was also adopted

by the Spanish painter Joan Miró and the French painter André Masson (see fig 2.5).

Other techniques that employ elements of chance include (de Moraes Cardoso, 2016):

- Decalomania: Thick paint is spread upon a canvas before covering it with paper or foil. The covering is subsequently removed before the paint dries, revealing an unpredictable pattern beneath.

- Frottage: Paper is placed on a textured surface and a rubbing is taken. Complex effects can be achieved by combining multiple rubbings within one drawing, which can subsequently be coloured, cut up, or combined with other materials in collage.

- Cubomania: A surrealist method of making collages in which a picture is cut into squares which are then reassembled without regard for the original image.

- Grattage: A process of scraping paint from a surface with a blade.

- Froissage: A screwed up sheet of paper is smoothed out and soaked in coloured inks. The creases take up the ink, creating a veined effect.

Fig. 2.5 –Automatic Drawing (Masson, 1924)

Aleatoric approaches have also been used in experimental photography to achieve spontaneity through chance. Lomography, a style of pop photography based around the Austrian ‘Lomo’ camera, is described as being *a spontaneous, candid view on photography* (The Dark Room, 2016) where the photographer just points and shoots (with no viewfinder) to acquire unpredictable images (e.g. fig. 2.6).

Fig. 2.6 - Lomographic example of aleatoric photography (Lumography, 2017)

In all these examples, the intention is to elicit emotional responses from the beholder, facilitated by the use of randomness. Whether in the form of surprise, joy, curiosity, bewilderment or potentially even frustration or disappointment, the same emotions can typically be experienced in response to products. The aforementioned typology of emotions described by Desmet (2004) can be used to illustrate this. By eliciting positive emotions (e.g. joy) a product can be perceived as attractive. By the same reasoning, negative emotions (e.g. disappointment) are clearly undesirable and should generally be avoided by designers seeking to elicit a positive emotional response. Indeed, designers themselves could benefit from the unpredictability that randomness provides. Whether attempting to create a novel and inspirational three dimensional form or just attempting to break through ‘designer’s block’, it is reasonable to suggest that random techniques (such as ‘automatic drawing’) could be used as a means of unlocking the potential of the subconscious mind and enhancing creativity.

2.6.1 Types of Randomness

Randomness relates to the statistical probability of an event and to what extent it is predictable. According to Kolmogorov's theory of randomness the degree of unpredictability of a random-looking sequence may be ascertained by testing batches to differentiate between truly random sources and complexity (which in the long-run may be found to contain patterns). Where a seemingly random pattern exists, it might be regarded as 'quasirandom', implying a kind of artificial randomness. The matrix in Fig 2.7 illustrates the relationship between the various types of randomness and order (Hemmings, 2005):

- The Random and Quasiorder quadrants both incorporate some element of randomness, but may be perceived in different ways.
- The Random and Quasirandom quadrants may be perceived as random, despite Quasirandom achieving this with no truly random element.

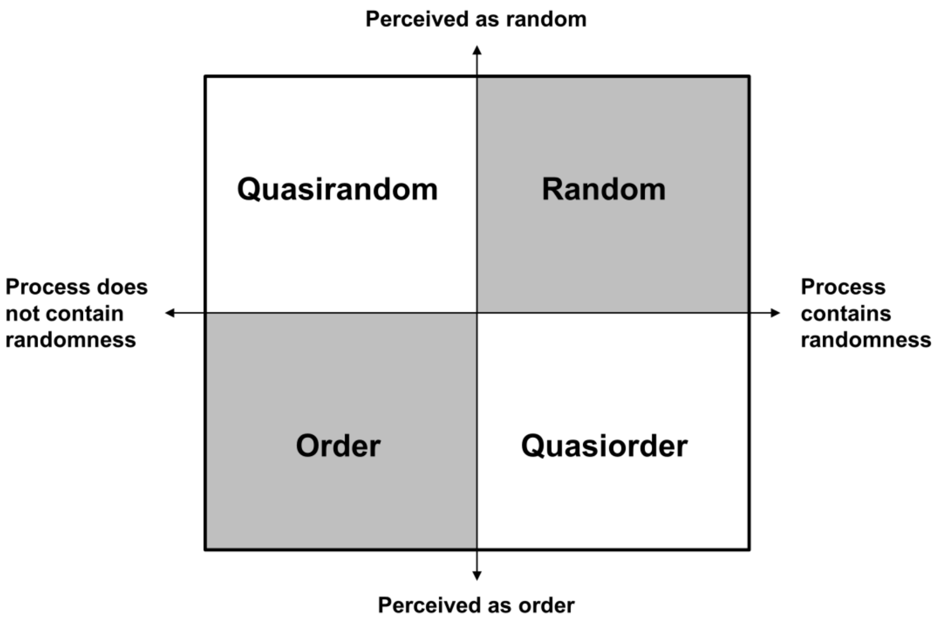


Fig. 2.7 - Differing perceptions of order and randomness (Hemmings, 2005)

Quasirandomness occurs where randomness is perceived despite an ordered process. For example, the drip paintings made famous by Jackson Pollock (e.g fig 2.8) were achieved through an emotionally driven, physics-inspired technique (Sooke, 2016), although they are often misconstrued as random splatters. His ‘action painting’ technique was highly expressive. He would become immersed in the act of painting rather than concerning himself with the completed result (Jackson-Pollock.org, 2011). In these instances, the emotional response preceded the artefact rather than the other way around. The final painting is therefore a product of the artist’s emotions and, despite the seemingly chaotic splatters on the canvas, not a random process.

Fig. 2.8 - Summertime: Number 9A (Pollock, 1948)

Pseudo-randomness and quasirandomness are similar terms. Carl Ellison provides the following definition:

A PRNG (pseudo-random number generator) is a function which takes a certain amount of true randomness (called the seed of the PRNG) and generates a stream of bits which can be used as if they were true-random […] (Ellison, 1995)

CAD software such as 3DSMax generates random variables in this way using a PRNG (Lama, et al., 2007). The designer or CAD operator determines the upper and lower thresholds for the parametric constraints. The software then applies an algorithm to produce an apparently random result, and by combining many pseudo-randomly generated features within a single concept the overall outcome becomes less and less predictable. By changing the seed each time the software is started the output can be perceived as entirely random, even though it contains elements of quasirandomness.

Normal computers are incapable of creating truly random numbers by themselves. They create a pseudo-random random output using an algorithm. This algorithm is unpredictable so that, for most purposes, it can be considered as random. A PRNG can be hacked if the algorithm is known and the seed can be determined. Where a truly random output is required (such as ERNIE, the computer that selects premium bond numbers for UK National Savings and Investments) a computer can be connected to an analogue device capable of generating random noise (Fairhead, 2013).

2.7 Chapter Summary

Emotions are complex and can be viewed from philosophical, physiological and psychological perspectives. However, the main findings of the literature review indicate that they can also help to explain the otherwise intangible relationships between people and the objects they choose to acquire and interact with on a regular basis. By understanding some of these concepts, designers can better equip themselves for the task of creating products capable of meeting the needs of people and industry.

‘Design and emotion’ is a relatively new discipline within the larger context of design and engineering, but it is one that has already stimulated much research in its field. Established tools and techniques such as Kansei engineering have been applied with significant success and continue to draw the interest of practitioners and researchers alike. In seeking to better understand people’s emotional needs, as well as their physical ones, designers and design researchers aspire to developing products and approaches that will (amongst other things) help manufacturers procure market supremacy and brand recognition.

From its primary application as a replacement for the draughtsman’s board to fully integrated systems for full product lifecycle management, the field of CAD has expanded, just as computers have become an integral part of people’s lives in general. As with traditional workshop tools, a CAD tool can be general purpose or highly specialised. The designer must choose which tool to use and when to apply it in much the same way as a craftsman would. For it to be effective, it is as important that the tool itself is as fit for purpose as the final product design it is used to create.

Creativity is generally considered a pre-requisite of any good designer. But humans tend to be creatures of habit, naturally falling into familiar routines when there is a lack of appropriate stimulation. Randomness provides opportunities for unexpected events to occur. Randomness has successfully been used to augment lateral thinking, enrich concept diversity and enhance creativity. In the right context, randomness can even elicit emotional responses. It should therefore be reasonable to suggest that randomness could be used within the design process to create products capable of eliciting emotional responses. The literature reviewed supports the idea of imbuing a CAD tool with the ability to surprise and inspire designers by eliciting positive-surprise responses to product design concepts.

3. Research Methodology

3.1 Introduction

This chapter discusses the research design, including the philosophy, approach and methods used to formulate, refine and address the research question. Information is provided regarding the design of experiments and studies used for data collection. In addition, an ongoing process of informal experimentation ran in parallel with the formal studies. This experimentation centred on the investigation of a suitable CAD engine and interface within which to create a viable tool for emotional design. Details of this process including the identification and creation of key parameters are also provided as appropriate throughout this chapter.

3.2 Research Philosophy

A pragmatist research philosophy was adopted from the outset of this PhD research project. Saunders et al (2009) argue that this approach is most suited where there is an open-ended nature to the research and an absence of a clear hypothesis. Furthermore, the personal and potentially subjective nature of the way emotions can be experienced in response to product design meant that there was the potential for multiple valid points of view. The chosen methodology employed a variety of mixed research methods, including a qualitative pilot study and quantitative experiments. The pragmatic approach complimented this, as well as the development of the research question as the research progressed and new data was assimilated.

3.3 Research Strategy and Approach

A preliminary research strategy was drawn-up in an attempt to identify routes of further research (see fig 3.1), (Reynolds, 2010). The pragmatist approach that had been adopted meant that it would be appropriate to guide the development of the research question using the data collected. An initial pilot study was proposed that would investigate a preliminary research question:

How do people respond emotionally to images of products that they're encountering for the first time?

It was anticipated that the outcomes of the pilot study might inform the subsequent research direction and set the backdrop to the formulation of the main research question.

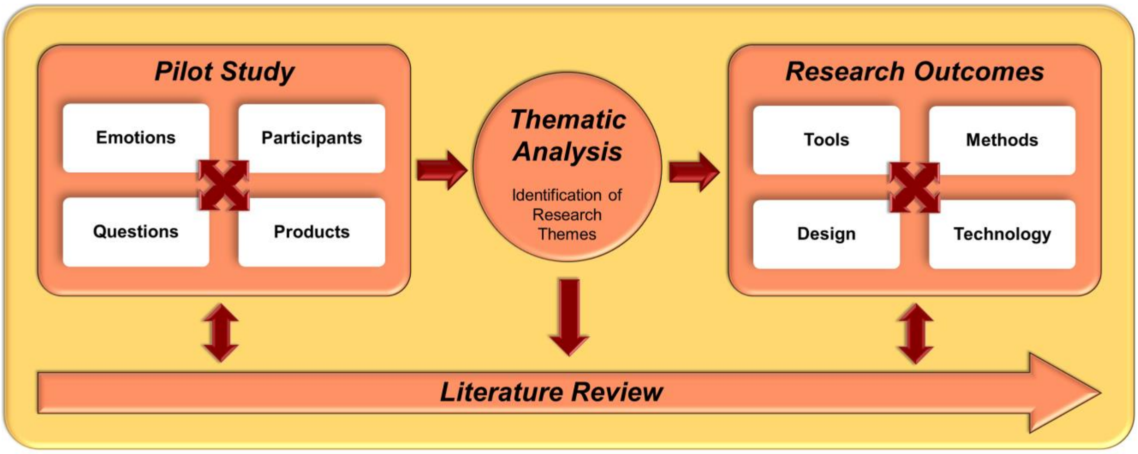


Fig. 3.1 - Preliminary Research Strategy Diagram

The pilot study confirmed that pictures of products could elicit a range of initial emotional responses. It was therefore logical to infer that design concepts created and viewed in appropriate CAD software should be capable of eliciting comparable emotional responses. However, the breadth of conceivable emotional responses meant that:

- The variety of responses could be diverse.
- The means of recording the responses accurately would be complicated.
- The resulting data analysis could be highly complex.

Experimentation (that was being undertaken in parallel to the pilot study) had resulted in the creation of a prototype CAD tool that was capable of generating product design concepts for a single product type. A quantitative 'exploratory study' was devised to test the application of the CAD tool within the context of design and emotion.

The aims of the exploratory study were to:

- Test the application of a CAD tool in the context of design and emotion.
- Gain additional insight and focus to refine the research question.
- Prelude a more detailed study to investigate the main research question.

A more detailed research strategy was proposed (see fig 3.2) which anticipated a further, more detailed 'main' study to follow. However, the research strategy remained flexible in order to accommodate any unexpected results.

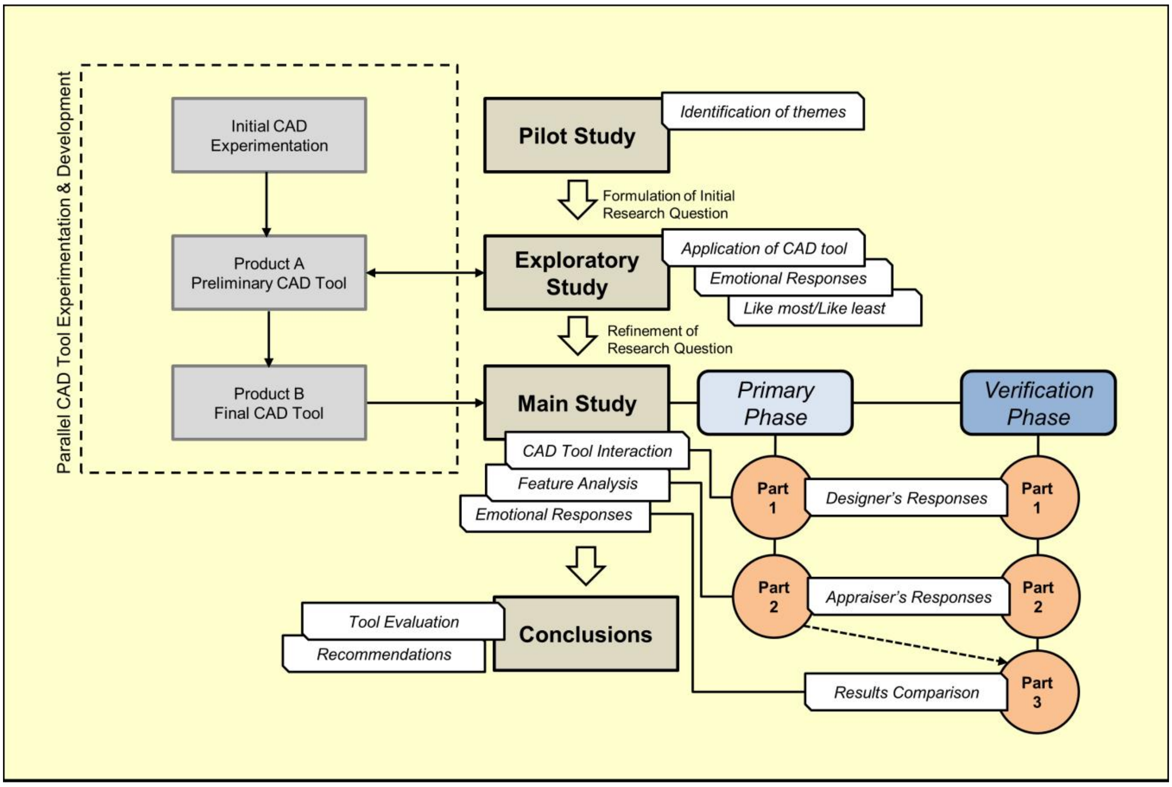


Fig. 3.2 - Diagram showing overall research methodology

The findings of the exploratory study, in conjunction with further ongoing CAD tool experimentation, informed considerable alterations made to the research question. These included, most significantly, the application of randomness as a mechanism for emotional design. A final iteration of the research question was posed as follows:

Is a pseudo-random CAD tool an effective way of generating affective product design concepts?

The primary objective of the main study would be to establish whether there was a discernible difference between the emotional responses elicited by manually created product design concepts and those created using random variables. Some additions were made to the research question in an attempt to gain further valuable insight from the findings (see chapter 1.5). Essentially, these would seek further expansion on such aspects as whether the appeal of the concepts differed; the strength of the emotional responses elicited by the concepts differed; the existence of a relationship between likeability and strength of emotional response; and which geometric features (if any) elicited the strongest emotional response.

Unlike the exploratory study, the main study would also seek to capture the designer's experiences of interacting with and applying the CAD tool as it was considered pertinent to gain feedback from a potential user group. This meant that it would be necessary to engage a number of appropriately skilled and capable designers, as well as a group of individuals to respond to the design concepts produced. To that end, final year undergraduate volunteers were recruited from the BA Industrial Design course in the department of Science and Technology at Bournemouth University.

The main study consisted of two separate phases, the latter being entirely independent of the first to act as verification. The aim of the main study was to resolve the project and obtain answers to the final research question. All studies undertaken were cross-sectional in nature regardless of their means of data collection and analysis.

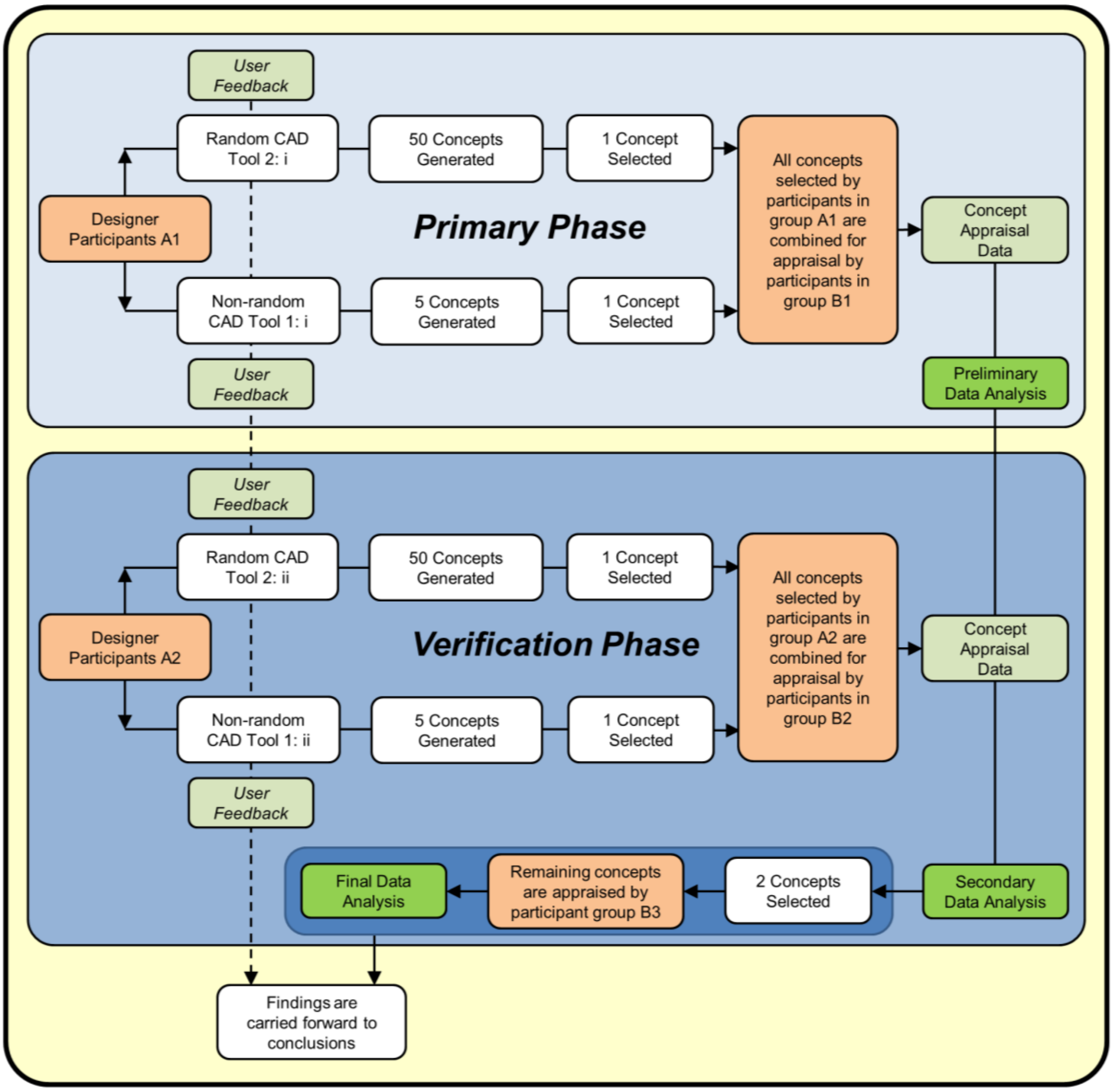


Fig. 3.3 - Diagram showing the research strategy for the Main Study

A Primary phase was devised to investigate the application and output effect of the ‘Vase Maker’ CAD tools. It was comprised of two separate parts: The first part focused on the designer’s experience of interacting with and applying each design tool in turn. The second part sought appraisals of the concepts that the designers had created using both tools. A second, Verification phase was then undertaken, in an attempt to validate the results of the Primary phase and to expand the overall data. Each phase was further broken down into two parts as shown in fig. 3.3. A third part was added to the Verification phase following analysis of both sets of results. In this final element of the study, the top performing concepts from each study were compared by a separate group of participants.

3.4 Research Context and Ethics

This PhD research project was undertaken within the faculty of Science and Technology at Bournemouth University. Many of the research methods that were used required access to students as study participants. Research ethics and the associated BU codes of practice were adhered to from the outset. Copies of the approved Ethics forms are available in Appendix B of this report.

Research ethics were considered ahead of the exploratory study with regards to the use of a questionnaire. Details regarding the purpose of the study were provided and, considering the contents and the fact that participants were able to participate entirely voluntary and anonymous, it was considered that there were no significant ethical issues. Respondents to the exploratory study's online questionnaire were entirely anonymous.

The main study was covered by a separate ethics review. Participants in the main study were final-year BA Industrial Design students at Bournemouth University. While participation was open to all eligible students, those volunteering to take part in the study were all western European (predominantly British), aged between eighteen and twenty five and of mixed gender. All were known to the researcher in a professional academic capacity (only). It was considered that, in the context of the study being undertaken, the relationship between the researcher and participants posed little threat to the credibility of the results. Despite this, precautions were taken to ensure that no hypothesis or information regarding preferential responses was released to the participants throughout their participation. Additionally, considerable care was taken to ensure that there were no perceived incentives or benefits from their participation in the research.

The research strategy sought to collect data that was broadly relevant and applicable to the research aims. It was accepted that cultural and social attitudes may be factors for consideration when interpreting the data, depending on the participant sample. It was not envisaged that any part of the research would focus on distinct cultural or social groups, although it is accepted that the participants were all undergraduate students within a fairly narrow age group and ethnicity. While it was possible that study participants would fall within other such groups, there was nothing to suggest that was the case.

3.5 CAD Tool Prototype and Development

3.5.1 Introduction

A CAD tool must be capable of creating product design geometry without compromising the designer’s intentions. The nature of product design is such that the number of geometric possibilities grows exponentially with each new feature the designer adds. A simple straight line can be specified in terms of length, thickness and orientation, while more complex forms pose significant computational challenges. The initial objective of this research project was to test the application of a verbally controlled CAD tool for aesthetic augmentation. However, since no such CAD tool existed it was necessary to create a working prototype. An initial design specification was created that outlined the intended design criteria for the CAD tool, based on analysis of the problem. A suitable piece of CAD software was sought that offered the potential to meet the performance objectives set out in the specification. After some initial experimentation, a working prototype CAD tool was created with basic functionality. Preliminary testing was undertaken to establish whether the results met the minimum requirements set out in the specification. The results of those tests were used to refine the functions and the onward development direction of the CAD tool.

3.5.2 Specification

Contemporary design practice necessitates that designers work predominantly in a three dimensional (3D) domain from early on in the design process. There is therefore an expectation that a CAD tool should be capable of operating in real time in a 3D environment to create 3D product design concepts. While there are a variety of commercial software platforms available to support this approach, it was necessary to identify one that could offer the right attribute set for the specific objective. This included the ability to:

- Provide a suitable user interface

- Respond to verbal commands
- Operate in a way that is relatively intuitive and/or familiar to designers
- Translate design intentions into geometric modifications
- Display the results and export CAD data in a usable format

The user interface provided the outward appearance of the CAD tool, presenting the tool's functions and capabilities to the designer. An intuitive user interface reduces interaction time and mistakes and improves user satisfaction. Since a well-designed product can produce a positive emotional experience for its end-user, it seemed logical to deduce that a well-designed user interface should go some way to ensuring a positive emotional experience for the designer. It was considered important to achieve this objective so that the designer's experience of using the CAD tool was positive and conducive to creativity and productivity.

The user interface needed to incorporate appropriate mechanisms to control the various types of input required of a CAD tool. These included data entry values in numerical and verbal form as well as the potential incorporation of controls such as buttons (to switch features on and off) and sliders (commonly a graduated line with a single handle, moved with the mouse to adjust input variables). The controls needed to be presented in a coherent layout in which application precedence and sequence were implicit. It was considered desirable that provision was included to enable controls to be turned on and off or for the application of effects to be undone, in order to encourage experimentation and comparison of modifications by the operator. It was preferable for the CAD tool to be compatible with or integrated into existing CAD environments with which designers may have had some level of familiarity. The mode of operation was intended to be intuitive or familiar to reduce operator error.

The primary function of the CAD tool was to create a diverse range of product design concepts for one or several types of products. A broader range of product types potentially increases CAD tool complexity in terms of user interface and function. Therefore, a single product category or a group of product categories that share common characteristics was chosen as the test-bed for the CAD tool prototype. It was also preferable for the chosen product type to require relatively few parametric variables, to reduce the computational complexity of the initial prototype and the data it produced.

The CAD tool needed to be capable of creating product design concepts either from an initial set of values and descriptors, or by creating a primitive concept to which the desired modifications could subsequently be applied. The breadth and depth of conceivable modifications needed to be sufficient to inspire creative expression while remaining controllable. The types of available modifications were representative of features suited to the product type and not profoundly detrimental to the fundamental function of the intended product concept. The verbal controls needed to be apparent or implied in such a way that the CAD tool operator could deduce suitable input descriptors in order to obtain an appropriate output effect. The CAD tool would either need to incorporate a means of interpreting the designer's verbal inputs, or present the available verbal commands (e.g. in the form of a list of options), preferably in a context specific manner. If the provision had been made to allow operators to input their own verbal descriptors, a knowledge base and inference engine would have been required to interpret incoming data and translate it into an appropriate geometric modification.

The user interface and associated CAD model ideally needed to be presented simultaneously in a familiar on-screen environment with neither proportion nor positioning being disadvantageous to the design task. The impact of colour was neutralised where possible, but not to the extent that design capabilities were diminished. The CAD model was represented in 3D and it was preferable that manipulations of the CAD model view be possible using typical rotate, pan and zoom controls. It was possible to extract geometric CAD data pertaining to the construction of the CAD model for subsequent analysis, replication and augmentation, directly from the CAD software.

3.5.3 Initial CAD Tool Function and Operation

To meet the requirements outlined in the design specification, a number of potential candidate software platforms and programming languages were identified for consideration (including Blender, Python, C++, AutoLisp and 3DSMax/MaxScript). 3DSMax was ultimately selected for preliminary testing due to its relative ease of use and accessibility. In addition, 3DSMax is an established, industry standard piece of CAD software with which many individuals operating in the field of design should be familiar.

After some preliminary experimentation, a scheme was proposed for the development of a CAD tool prototype. Tables were chosen as the product type upon which the initial prototype would be tested. As such the initial prototype was given the working title ‘Table Builder’. Tables were chosen as a subject for the prototype due to the potentially small number of attributes that need to be defined in order to produce a recognisable, functional concept.

The CAD tool itself was created in MaxScript, which is a scripting language integrated within 3DSMax (Appendix C). MaxScript offers the ability to control all aspects of 3DSMax including the creation of user interfaces (termed ‘rollouts’) and macros for modelling and rendering. The MaxScript environment includes all standard arithmetic and logic functions as well as the fundamental aspects of a programming language, sequence, selection, repetition and procedure.

The basic function of Table Builder was to create a table and facilitate modifications via the application of verbal commands. The script operated as soon as it started (using the appropriate command within 3DSMax). The initial script sequence was as follows:

Clear old UI rollouts

Create new UI rollout

Predefine parametric variables

-- Await input from operator --

The initial table was created once the shape (rectangular or elliptical) and X, Z dimensions for the table top were defined by the operator. Other variables such as initial leg X,Y and Z dimensions were initially predefined within the script. Once the required information was provided by the operator the sequence continued as follows:

Create initial Table geometry

-- Await input from operator –

From this point in the script, the sequence of operation was determined by the operator’s selection of modifiers, controlled by the buttons and sliders presented on the user interface. Each modifier was defined within the script in the form of a sub-routine which could be called in any order the operator desired. The values assigned to each variable were predefined. These predefined values were judged to be the most appropriate based on findings from experimentation during the tool’s development. The modifiers could be applied recursively to increase the magnitude and intensity of the effect, or in series combination to achieve cumulative effects. 3DSMax applies modifiers sequentially in a ‘modifier stack’. Modifiers can be moved up or down within the stack, but the precise resultant effect of a series of modifiers depends on the specific sequence of application within that stack, i.e. A+B+C ≠ A+C+B

Table Builder’s functional capabilities were restricted to two basic types of table: a) extruded circular/elliptical top with four cylindrical legs; and b) extruded square/rectangular top with four cuboid legs. While the inclusion of other predefined table top shapes with different numbers of legs would have been possible (e.g. triangular with three legs) such additional functionality was not included for the purpose of the initial prototype for reasons of expediency. The basic functions of the Table Builder CAD tool included the options to:

- Build or delete the current table concept
- Recursively apply a verbally described ‘Proportion’ or ‘Style’
- Recursively modify table top and table leg proportions
- Add/remove a ‘Bend’ and ‘Taper’ modifier to the table legs
- Turn on/off the smoothing effect
- Turn on/off the distortion effect

A selection of what was considered to be the most suitable modifiers was incorporated into the CAD tool to facilitate greater design expression and experimentation. Furthermore, an attempt was made at producing predefined design ‘styles’ that worked by combining certain modifiers in a predetermined sequence to achieve cumulative effects. This method was used instead of verbal data entry for the purpose of the initial prototype as it was considered more pragmatic at the early stage of design and testing. The selection criteria and description for each modifier (and style) were initially based on an appraisal of their overall effect on the CAD model when compared with commercially available products of a similar type. The function groups provided predefined effects that could be applied to the CAD concept in any sequence. In many cases, a repeated application of a modifier intensified its effect:

Proportion:

- ‘Slender’ applied the ‘stretch’ modifier to create a vertical stretched effect to all table entities simultaneously.
- ‘Chunky’ increased the thickness of all table entities simultaneously.
- ‘Dumpy’ increased thickness of all table entities and reduced the table leg length simultaneously.

Style:

- ‘Classic’ added the taper modifier to draw all the legs towards the middle of the table at the feet.
- ‘Gothic’ added the taper and noise modifiers to create a gothic furniture effect to all the legs.
- ‘Curvy’ added the taper and bend modifiers to bend all the legs and draw them outwards from the middle of the table.

FX:

- ‘Smoothing’ added/removed a small radius to all edges.
- ‘Distortion’ added/removed a distortion effect to all the legs.

Modify:

The Modify group was arranged into four main areas:

- ‘Thickness’: The thickness of the table top or all the legs.
- ‘Leg length/position’: i) Move all the legs simultaneously along a diagonal path towards or away from the centre of the table or; ii) adjust the length of the legs.
- ‘Bend Amount ‘: Bend all legs simultaneously along a diagonal path towards or away from the centre of the table.

- ‘Taper Amount’ –Narrow of all the legs simultaneously towards the feet.

The tool also allowed the designer to add/remove two additional and independent predefined effects: distortion and smoothing. With the exception of these effects the modifiers used to create the styles were entirely controllable via parametric variables written into their code. The distortion effect (which applied only to the table legs) was created using the ‘noise’ modifier. The control parameters for this modifier were limited to scale and strength so it was not possible for it to be refined or manipulated further. Smoothing added the ‘meshsmooth’ modifier by a predetermined amount to remove sharpness at the edges of the CAD model and improve visualisation.

3.5.4 User Interface (UI) Design

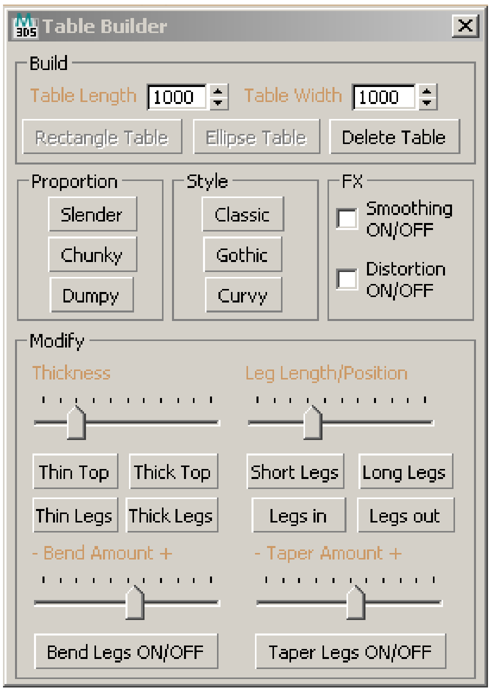


Fig 3.5 - Table Builder User Interface

The Table Builder CAD tool provided context specific functionality within a contemporary CAD environment. The tool’s UI (fig 3.5) was designed to be intuitive in a way that made it accessible to anyone with a basic understanding of CAD. It should not be have been necessary for the operator to have a working knowledge of 3DSMax to be able to fully exploit the CAD tool’s capabilities (although this is something that would be advantageous should subsequent modification and manipulation of a chosen concept be desired). The UI was presented as a graphical menu of options, which appeared on-screen alongside the CAD model itself. The UI provided access to the tool's functional capabilities and control over the intensity of their application. The controls were arranged in a three stage vertical hierarchy to indicate a suggested sequence of operation.

Build: Placed at the top level of the UI to indicate precedence. Settings at this level needed to be selected before the rest of the UI became active. 'Spinner' controls allowed the operator to adjust values using the mouse, or to enter numerical values directly. Build 'button' controls were initially enabled for the user to select the type of table to create (elliptical or rectangular). Once selected, these buttons were disabled and the 'Delete Table' button became enabled. Selecting the delete table button disabled the delete button and re-enabled the build buttons.

The Proportion and Style groups were at the intermediate level and facilitated the application of modifier groups via dedicated button controls. These buttons could be selected repeatedly to allow recursive application of the effects. The Smoothing and Distortion effects resided on the same row to imply their association with the Style group. The 'checkbox' controls indicated that the effect was either on or off.

The Modify group was at the lowest level, although in practice the operator was at liberty to go back and forth between the controls at this and the intermediate level. The modify group offered the most interactive of the available features:

- 'Thickness' – The incremental magnitude was adjusted using a slider control. Buttons selected whether to adjust the thickness of the table top or legs by the increment shown. This effect could be applied recursively.
- 'Leg length/position' – The incremental magnitude was adjusted using a slider control. Buttons selected whether to i) move all the legs simultaneously along a diagonal path towards or away from the centre of the table or; ii) adjust the length of the legs, by the increment shown. This effect could be applied recursively.

- ‘Bend Amount ‘– The magnitude was adjusted using a slider control and a button applied the modifier to bend each leg simultaneously along a diagonal path towards or away from the centre of the table by the increment shown, or removed it entirely.
- ‘Taper Amount’ – The magnitude was adjusted using a slider control and a button applied the modifier, narrowing of the leg towards the feet by the increment shown, or removed it entirely.

The CAD model responded to user inputs instantaneously in real time. 3DSMax automatically records references to each modifier within the modifier stack. These values were stored in the model file and could be accessed at any time should subsequent scrutiny or alteration be required.

3.5.5 Preliminary Testing

Initial testing was undertaken to explore the capabilities of the CAD tool in relation to the research problem. It quickly became evident that the breadth of possible permutations of combined modifiers is extensive. This was exacerbated by the impact of modifier sequence within the modifier stack. The order in which modifiers appeared in the stack affected their outcome on the CAD model. As more modifiers were applied, the number of potential permutations rose exponentially (i.e. three modifier layers could be applied in one of six possible permutations, four modifiers in twenty four possible permutations, five modifiers in one hundred and twenty possible permutations and so on). While the effect of some modifier combination appeared subtle with only marginally differences, many more significantly different permutations were found to be evident during testing.

The initial development of the CAD tool prototype was undertaken partially in parallel with the pilot study. An exploratory study was then devised to test aspects of the CAD tool. In particular, this would seek to ascertain the ability of concepts produced by the tool to elicit a positive emotional response. Feedback from both the pilot study and exploratory study informed the CAD tool’s further development direction.

3.5.6 Development of a Random CAD tool

Following the pilot and exploratory studies, the emphasis of the research project shifted somewhat from its initial objective; i.e. to investigate the use of verbal descriptors in a CAD tool for affective augmentation of product design concepts. The new direction would explore the potential use of randomness to create emotional responses both during and as a result of the concept generation process. The verbal requirement of the UI was therefore made obsolete as it was no longer relevant to the remainder of the work. Following analysis of the results from the exploratory study, further developments were sought to enhance the CAD tool's functionality and feasibility for affective augmentation of product design concepts.

Product Type

An important development objective was the ability to apply the CAD tool to a different product type. It was considered necessary to test the CAD tool on a different class of products in order to test its general application. It was also anticipated that this might reduce the impact of misinterpretations made regarding the emotional responses elicited by the product design concepts, were they to be influenced considerably by the product type. The type of product (tables) has a strong functional emphasis, and people generally interact with a variety of them on a daily basis. It was considered possible that this might affect the way people perceive a new concept, regardless of whether they find its form appealing at a purely aesthetic level. That is, that a design that does not *look* fit for purpose might well elicit a strong, negative emotional response.

Derivatives of the Table Builder script were adapted to a number of other product types during interim experimentation following the exploratory study. These included smartphones and cameras with mixed success. However, Smartphones were ultimately considered to be potentially unsuitable due to the high levels of familiarity and brand loyalty often shared by owners of these types of products. Products such as cameras were found to consist of a large number of individual features that require a far greater number of variables to comprise their overall form. For example, the design of a camera's shutter button alone can be expressed in a myriad of different ways. The complexity of the camera's design subsequently increases exponentially, since each feature may essentially be regarded as a separate concept in its own right. The level of product complexity therefore has a bearing on the complexity of the CAD tool. This was a significant consideration as complex data containing potential contradictions in response to individual features could prove difficult to analyse and interpret. A further consideration was the significant development lead-time and level of programming expertise required to create such a tool.

A product type was sought that would, by virtue of its function, possess a high aesthetic value. Furthermore, as with the tables in the exploratory study, a product that could be relatively simple was deemed to be preferable as it would reduce the likelihood of individual features creating confusion that could potentially affect the overall emotional response. To that end, vases were chosen, being judged to meet the necessary criteria in that they:

- Perform a function, i.e. to hold flowers/a flower.
- Are predominantly made in one piece, from one material.
- Generally share similar basic features.
- Are generally considered to be decorative items and thus hold significant aesthetic value.

CAD Tool Function: Non-random and Random

Another development objective was to incorporate an element of surprise within the CAD tool. Surprise was identified in the pilot study as having the potential to augment emotional responses. It was considered that surprise might also play a significant role in augmenting the designer's creativity during the concept generation process (Gonzalez , 2005). The Table Builder tool could only generate concepts based on the designer's deliberate inputs. While the combined effects in the 'style' groups could produce unexpected results, any element of surprise would have the tendency to diminish as the tool became more familiar to the operator.

MaxScript is able to generate pseudo-random values for any variable. A pseudorandom number generator (PRNG) is a nondeterministic means of creating number sequences. The PNRG starts by generating a random number known as a 'seed'. The seed can be generated in a variety of ways (e.g. the current time or a measurement of electrical noise), but the same seed will generate the same pseudorandom sequence each time.

During the interim experimentation that took place following the exploratory study, the creation of a random CAD tool prototype was initiated. The first iteration of this CAD tool prototype was designed to generate Smartphone design concepts of different overall proportions using randomly generated parametric variables (Appendix D). The inclusion of parametric relations within the script made it possible to create concepts with random proportions while maintaining other proportions such as screen, microphone and speaker locations relative to the overall randomly generated dimensions.

Following selection of a product type, schemes were put in place to develop two modified iterations of the CAD tool (hereafter referred to as the Vase Maker tool) (Appendix E). The first of these was a non-random CAD tool based on the Table Builder tool that worked in a similar sequential fashion:

Clear old UI rollouts

Create new UI rollout

Predefine parametric variables

-- Await Start command from operator –

Once the 'Start' button is selected by the operator an initial hollow cylinder is created with predefined and X, Y dimensions as follows:

Create initial Vase geometry

-- Await input from operator –

At this point in the script, four 3DSMax modifiers (twist, bend, stretch and squeeze) are applied automatically with null values. The modifiers facilitate the geometric manipulation of the concept's geometry. They were selected based on their ability to create effects and forms typically associated with products of this type (See Appendix F):

- Twist angle: The amount of rotation applied to the vase opening relative to the base, about the vertical axis.
- Bend angle: the angle that the vase opening deviates from the vertical axis.
- Stretch: A vertical elongation that creates a thinning effect about the middle of the vase. The opposite effect can be created by using negative values.
- Squeeze: Similar to stretch, applies a thinning effect to the middle of the vase, or the opposite effect when negative values are used.

The null values are initially applied within the script to render each effect invisible until the associated slider control is adjusted in the user interface. Any interaction with a slider control is immediately translated into a modification on the model, making the action highly controllable and interactive. This had the advantage of removing the need for separate buttons to apply each modifier. As with Table Builder, each modifier is defined within the script in the form of a sub-routine which can be called in any order the operator desires. However, unlike Table Builder, the modifiers in Vase Maker are applied directly upon the operator's adjustment of the sliders. Additional buttons are provided to incrementally adjust the vase's overall proportions including height, diameter and ovality.

By default, each modifier is added sequentially one by one to the modifier stack. With Table Builder, when a modifier setting is selected an additional modifier is called and added to the stack, intensifying the effect. The order in which modifiers appear in the stack also affects the CAD model's appearance. The combination of these factors means it can quickly become difficult for the operator to track their concept's progress. To simplify the tool's operation, testing was undertaken to identify an optimum sequence of modifier application. Certain permutations of modifier combinations could be highly unpredictable. While this is potentially a good thing when seeking to elicit emotional responses using a CAD tool, many of the results were found to be impractical or non-representative of the product type. To maintain parity between the capabilities of both iterations of the CAD tool, changes were made to simplify the modifier application sequence.

The first change was the addition of a 'deletemodifier' command within each slider control sub-routine, e.g.:

```
on sld_tw changed val do
                    (
                              for base in objects do for m3 = base.modifiers.count to 1 by -1
where classof base.modifiers[m3] == twist do deleteModifier base m3
                              (
                              tw = twist angle: (sld_tw .value) bias: 50
                              addModifier base tw before: 3
                              )
                    )
```

The recursive nature of the sub-routine means that, while the slider is being adjusted, previous instances of that modifier are repeatedly overwritten. The second change was the addition of an 'addmodifier…before' command at the end of each sub-routine, to fix the sequence of modifiers within the stack, e.g. in the script excerpt above, the twist modifier is fixed at position 3. The combined effect of these changes made the operation of the non-random CAD tool substantially more controllable and intuitive.

The second version of the Vase Maker tool was based on the first, but the parametric variables controlled by the operator were replaced by pseudo randomly generated variables. The random variables were constrained by upper and lower limits, determined by a process of experimentation (Appendix G) with the non-random tool to achieve parity between the two (Table 3.1).

Parameter	Variable Constraints
Height	200 to 400 (mm)
Outer Diameter	50 to 100 (mm)
Twist: Angle	0 to 900 (degrees)
Twist: Bias	0 to 50
Bend: Angle	0 to 30 (degrees)
Stretch: Amount	-0.5 to 0.5
Stretch: Amplify	1 to 10
Squeeze: Bulge Amount	-0.1 to 0.5
Squeeze: Amount	-0.5 to 0.5
Squeeze: Bulge Curvature	-10 to 10
Squeeze: Curvature	0 to 0.5
Scale x, y, z	0.5 to 1.25

Table 3.1 - Random Feature/Modifier Sequence and Range

The random Vase Maker CAD tool works in a semi-automated fashion and creates vase concepts using pseudo-random functions. It is semi-automated in the sense that the CAD operator must initiate the creation of each new vase concept, at which point the designer can decide whether to keep the concept or delete it. Its initial sequence of operation was the same as that of the non-random tool, i.e.:

Clear old UI rollouts

Create new UI rollout

Predefine parametric variables

-- Await Start command from operator --

However, when the operator selects the ‘Add’ button, an initial hollow cylinder of random proportions is immediately created and modified in a predetermined sequence. Each time the random Vase Maker script creates a new concept, it applies four modifiers in the same sequence as those in the non-random tool. A total of fourteen pseudo-randomly generated variables are used in the application of the four modifiers. Some modifiers operate from multiple variables (e.g. the ‘Squeeze’ modifier requires four variables, see Table 3.2). The pseudo random values generated by 3DSMax can be integers or fractions. This means that sensitive parameters requiring variables in a very small range (e.g. Squeeze amount) can still benefit from a relatively high degree of randomness. The script for the random tool is relatively short and simple. However the pseudorandom variables used by the CAD tool are all entirely independent of each other, so the resulting overall level of perceived randomness should be high.

User Interaction and UI Design

As with the Table Builder tool, sequence of operation is implied by the layout of controls within the UI, starting with the create button at the very top of the rollout (fig 3.6). Sliders to control the four modifiers are presented in a large central panel. The sliders control the modifiers in real time with no additional button required for their application. The extent of each control is determined by variable set within upper and lower limits, assigned to each slider control as appropriate. Testing was undertaken to determine the desired extents of each slider. A slider range that was too small would mean the designers would find themselves overly constrained. Too large, and the on-screen CAD model would become very sensitive to the slightest input, making it hard to control and refine the features. Each slider generates a single value that can be used multiple times throughout the script. It was found that a satisfactory compromise between range and control could be achieved using a single variable within each multi-variable modifier, multiplying or dividing the value to provide a suitable order of magnitude. For example, the four variables used to constrain a squeeze modifier could be defined as follows:

Squeeze modifier	Slider range (s) = -0.4 to 1
Bulge Amount	s/2
Bulge Curvature	s/2
Squeeze Amount	s
Squeeze Curvature	0.5

Table 3.2 – Squeeze Modifier Definition Parameters

Buttons to adjust proportion are located at the bottom of the rollout. Aspects of the Table Builder's text driven UI were considered to be relatively rudimentary and were not found to be particularly intuitive or user friendly. This was partially attributed to the use of single word descriptions for tool functions that could be subjectively misinterpreted. MaxScript provides the option of using bitmap images to label buttons within a rollout instead of alpha-numeric characters. This is achieved by entering a reference to the image file's name and path at the appropriate point in the script. Custom made bitmap images were created using MS Paint, to form the icons, in an effort to make certain controls more intuitive and to enhance the overall look of the CAD tool UI.

In contrast, the random Vase Maker was operated using a single 'Add' button (fig 3.7). When the operator selects this button a vase concept the whole concept creation process is automated and a concept is created using pseudo randomly generated variables. No other controls were deemed necessary since basic controls such as 'delete' are already provided by 3DSMax via the keyboard and its own UI.

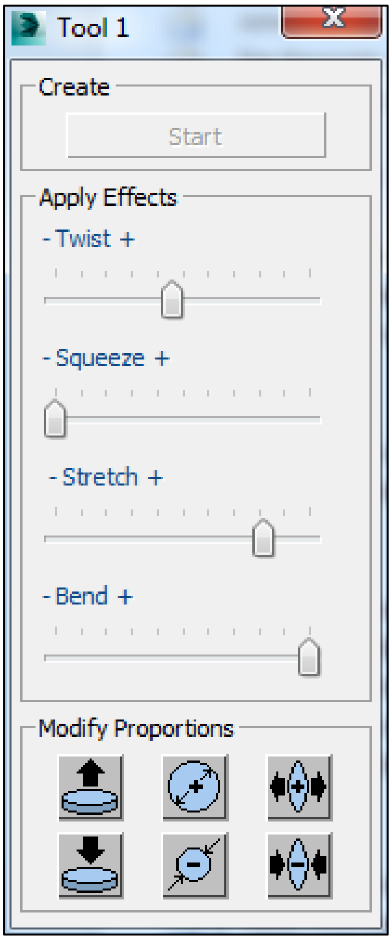


Fig. 3.6 - Non-random Vase maker CAD tool UI

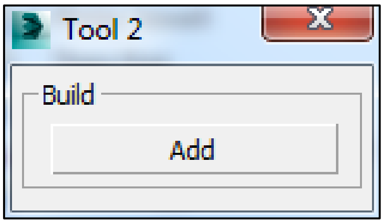


Fig. 3.7 - Random Vase maker CAD tool UI

Preliminary Observations

During testing, it was observed that concepts would occasionally be created that were quite unlike any that had appeared before. These occurrences were evidently the result of less probable combinations at the extremities of the parametric range. The easy, automated nature by which the concepts were created made the process enjoyable and entertaining. The anticipation of what might come next created a play-like level of intrigue. This relationship between play and creativity is a recognised phenomenon (Brown, 2008). Play is considered to be a liberating factor particularly amongst adults, when otherwise a tendency to pre-judge or edit ideas can be evident. The incorporation of this playful element was therefore considered to be a constructive addition to the design tool and congruent with the objective of enhancing the designer's creativity.

3.5.7 Summary

An initial prototype was created in accordance with a design specification for a verbally driven CAD tool in response to the research aim. As the project progressed, new findings and a shift of emphasis were assimilated. This altered the specification of the CAD tool and shifted the subsequent prototype development away from verbal control and towards randomness as a means of eliciting emotional responses. In addition, the desire to explore the tool's capabilities in relation to more than one product type meant that several iterations of the CAD tool were produced. This culminated in a pair of CAD tools capable of producing design concepts for the same product type, one of which used computer generated pseudo random variables to control geometric parameters and modifiers.

Pilot Study: First Contact Emotional Responses to Products

3.6.1 Introduction

The emotional aspect of design has broad scope and there has been considerable debate with regard to the way in which products can elicit different emotions and subsequently how people are attracted to the products around them. The particular area of interest for this PhD research project is that of the emotional responses evoked by *first-contact* with products. Specifically for the purposes of this research, the term *first* is used here to mean at a point which a potential consumer has no prior awareness of the product, and *contact* meaning visual contact rather than through physical touch. The pilot study was devised, as part of the pragmatist methodology, to help develop the research questions.

3.6.2 Aims and Objectives

The aim of the pilot study was to identify a suitable research direction for the ongoing PhD while gaining a better understanding of how people perceive products they encounter for the first time. The research objective of the pilot study was to answer the following:

How do people respond emotionally to images of products that they're encountering for the first time?

There was no particular hypothesis at this stage in the research. However, it was anticipated that certain outcomes would be observed in line with findings from the initial literature review, including that:

- Colour may be a significant element of a first contact emotional response.
- The extent of elicited emotional responses might correlate with those typically expected from encounters with product designs.
- People often find it difficult to articulate their emotional responses accurately using verbal means (Desmet, 2002).

3.6.3 Method

A small qualitative study using a semi-structured interview approach formed the basis of the pilot study. The aim was to identify themes for further analysis rather than to develop a theory. The types of questions most suited to this topic of investigation relate to the participants' opinions, feelings, and sensory experiences in relation to their first contact with products. However, interview technique can play a large part in determining the success of the overall study and the effectiveness of verbal data with regard to recording emotions has been called into question (Desmet, 2002) due to the different ways in which people perceive and then verbally express their feelings. Therefore, the nature of the open-ended questions and the semantics were intended to have a positive effect on the participants in order to encourage a rapport that was likely to be rich in data. Jargon or terminology that was likely to be outside of the participants' common use was generally avoided as this can have a negative effect on the participants. Furthermore, it was not assumed that the participants had sufficient knowledge of the subject matter to use technical terms without further clarification (Britten, 1995).

The subject matter itself, in this case products, could be made available either:

- physically
- as a facsimile model
- via an image
- in a video

Most people's first contact with a product tends to be via an image, article or advertisement. While tactile response is also an influencing factor, it was not the focus of this study. Therefore, a series of carefully selected, high quality images was used, although it was likely that the effectiveness of using images could be the focus of some scrutiny following the analysis of the results. The products were selected on the basis of various criteria including originality, typicality and design aesthetics (Reynolds, 2010) (fig 3.8).

The pilot study was undertaken within the faculty of Science and Technology at Bournemouth University. Participants in the pilot study were comprised of first year undergraduate Psychology students. Research ethics and the associated BU codes of practice were adhered to from the outset. Specific ethical approval was sought and obtained though the internal BU ethics procedure in place at that time (including obtaining permission from the relevant gate-keepers). None of the participants were known to or had any direct affiliation to anyone associated with the study.

The intended participants were to be comprised of mixed gender, aged between eighteen and twenty five. However, in the end only a limited number of subjects were forthcoming, all of whom were female. Since this was a speculative, qualitative study it was decided to continue (provisionally) on that basis. The acceptable number of participants in qualitative interview studies can typically be smaller than quantitative studies, because:

- data from interviews tends to be much richer in content than in quantitative studies;
- the purpose of the interviews is not to obtain an average or continuum of perspectives, just identify phenomena;
- the researcher has the opportunity to change course during the interviews to explore issues further, and capitalise on opportunities as and when they arise;
- the complexity and time involved in transcribing and analysing the data means that for the method to be feasible the number of participants must be manageable.

The data was analysed in light of the sample size with any apparent gender bias taken into consideration. Furthermore, the option of a second round was retained, should the results not prove useful, although this was not found to be necessary.

3.6.4 Product Selection: Rationale and Attribute Appraisal

i) **Ty Nant Water Bottle**: Non-mainstream brand. A simple product, but with complex asymmetric, organic surface detailing. Atypical design integrity for a commodity product. (Designer: Ross Lovegrove)

ii) **Supernatural Chair**: Simple, single component moulded chair with unusual organic form. Atypical design integrity for a one-piece moulded chair (Designer: Ross Lovegrove)

iii) **ASUS Eee PC 1008P Seashell Netbook**: Unusually brightly coloured casing for a personal computer. Surface texture provides additional visual stimuli. Photograph hints at function, but leaves much to the imagination re: user interface. (Designer: Karim Rashid)

iv) **Benchmade 755 MPR Lock-Knife**: Product shown both open and closed, illustrating functional attributes but in a benign context. Form is deliberately angular and rugged, creating a stereotypically masculine product in terms of form and function. (Designer: Shane Sibert)

v) **Alessi 'Piripicchio' Clothes Shaver**: Unusual product function and form. Colour and form make the product appear fun in character. Little to allude to the product's function and its physical features make the product look like a toy, detracting from its utilitarian function. (Designer: Stefano Giovannoni)

vi) **Black and White Heeled Sandals**: Contrasted black and white with highly reflective patent leather finish. Intricate detailing. Provocative form; highly angular with stiletto heels and clearly designed for visual impact rather than comfort or practicality. (Designer: Giuseppe Zanotti).

Fig 3.8 - Pilot Study Images

3.6.5 Summary

The pilot study was devised as part of a pragmatist research philosophy, to identify themes for further research in the area of emotional responses to product design. Based on initial findings from the literature review, it was anticipated that observations might be made regarding Norman's (2004) three levels of emotional processing. However, since this was a qualitative pilot study solely for the purpose of extracting research themes, there was no specific hypothesis. The study was undertaken with the participation of students of BA(Hons) Psychology at Bournemouth University.

3.7 Exploratory Study

3.7.1 Introduction

The exploratory study was designed to investigate whether significant emotional responses could be elicited from simple product design concepts created using a verbally driven CAD tool. This study also set out to investigate the relationship between emotional responses and preference, i.e. the link between the strength of emotional response and the likeability (or lack thereof) of a product design concept.

An initial CAD tool prototype had been developed using 3DSMax, to test its practical application for affective concept generation. The intention was to see whether significant, consistent emotional responses could be elicited from similar, simple product design concepts using a two dimensional CAD image.

3.7.2 Aims and Objectives of the Exploratory Study

The aims of the exploratory study were to:

- Evaluate the effectiveness of the (Table Builder) CAD tool as a means of generating affective product concepts.
- Establish an appropriate means of data collection with regards to aesthetic preference.

The following questions were proposed in order to address these aims:

1. Can a range of positive and negative emotional responses be elicited from simple CAD representations of product design concepts?
   Null hypothesis: The responses should not differ significantly.
2. Are concept preference (like/dislike) and the polarity (positive/negative) of elicited emotional response independent of one another?
   Null hypothesis: The factors are *not* independent of each other.
3. How does a concept's geometric proportion affect the emotional responses elicited?
   Null hypothesis: Geometric proportion alone does not significantly affect the emotional responses elicited by the concepts.

3.7.3 Method

The Table Builder CAD tool offers a range of modifications and transformations that can be applied in real-time to a 3D surface model. A test of the full capabilities of the Table Builder CAD tool was initially considered for the exploratory study. Initially, a series of 108 tables were created using the 'Table Builder' CAD tool prototype (see fig 3.9). The intention was to attempt to elicit emotional responses to a broad range of concepts in the exploratory study. However, after some preliminary testing, the large number of concepts was considered overwhelming, making the questions too difficult and time consuming to answer. In addition, it was apparent that data on this scale could unnecessarily complicate the data collection and analysis process.

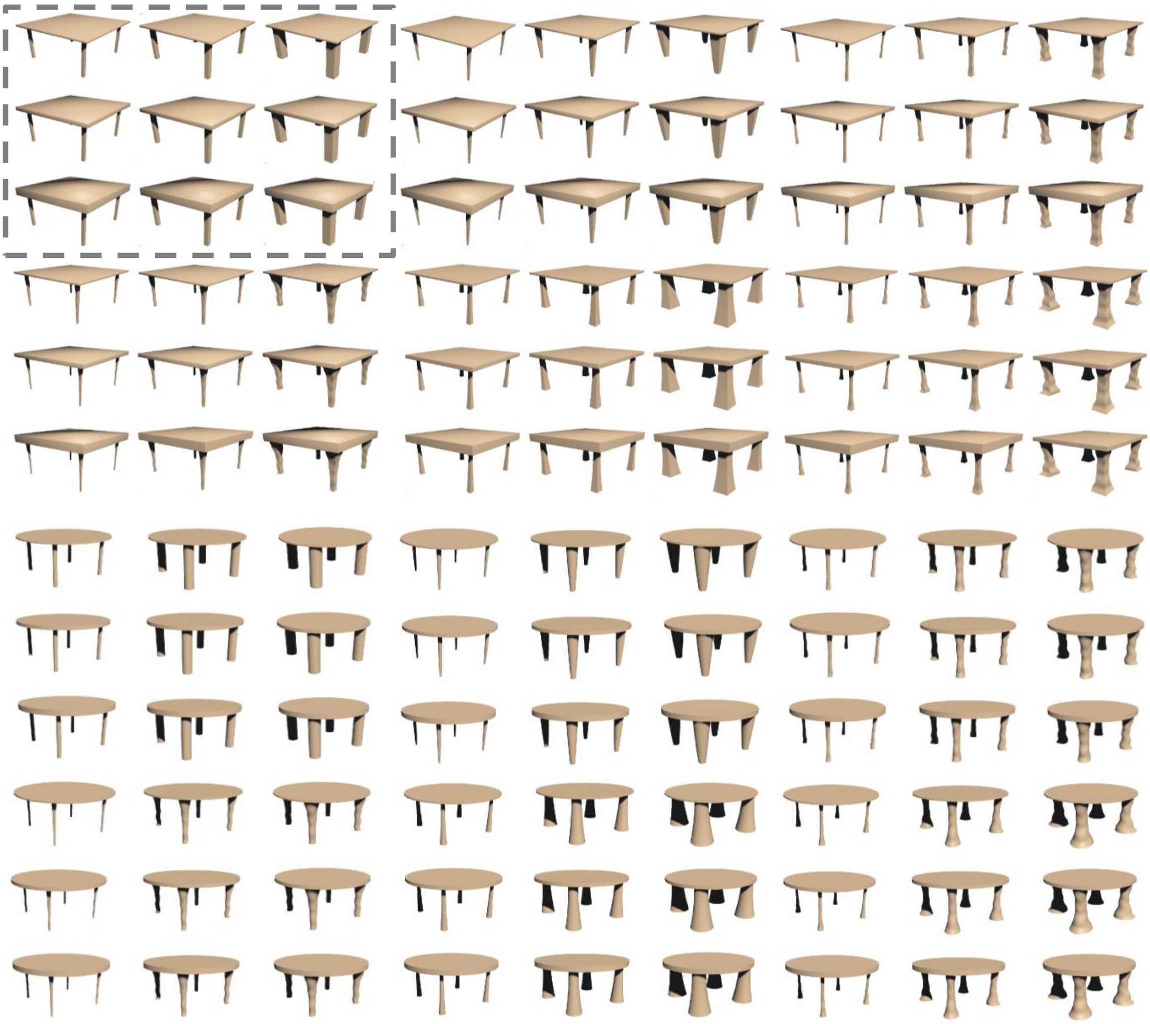


Fig 3.9 - Initial Series of Table Design Concepts

To simplify the data, the group of nine rectangular tables with no modifiers was used in the actual study (Fig 3.9 -top left). The simplest designs were chosen in order to minimise the number of parameters and to reduce the likelihood of confusing or misinterpreting results. All concepts were presented using the same scale, colour, lighting and orientation. Furthermore, all the tables were identical with the exception of two attributes (table 3.3)

Table-top thickness	Thin	A	D	G
	Moderate	B	E	H
	Thick	C	F	I
Table-leg thickness	Thin	A	B	C
	Moderate	D	E	F
	Thick	G	H	I

Table 3.3 – Table concept variables

The matrix in fig 3.10 shows the visual relationships between the nine concepts. Each row represents consistent table leg thickness, from thinnest to thickest table top. Each column represents consistent table top thickness from thinnest to thickest table leg. The diagonal line from top left to bottom right represents concepts with equal table top and leg proportions, while the two concepts in the opposite corners (bottom left and top right) represent the most extreme combinations.

The table concepts were pasted into an online questionnaire (via Survey Gizmo) and distributed via the internet (Appendix H). The benefits and drawbacks of using this method were considered, as were their potential ramifications on the survey results. To reduce the impact of colour the Table Builder CAD tool's functions were made solely applicable to three dimensional shape and form.

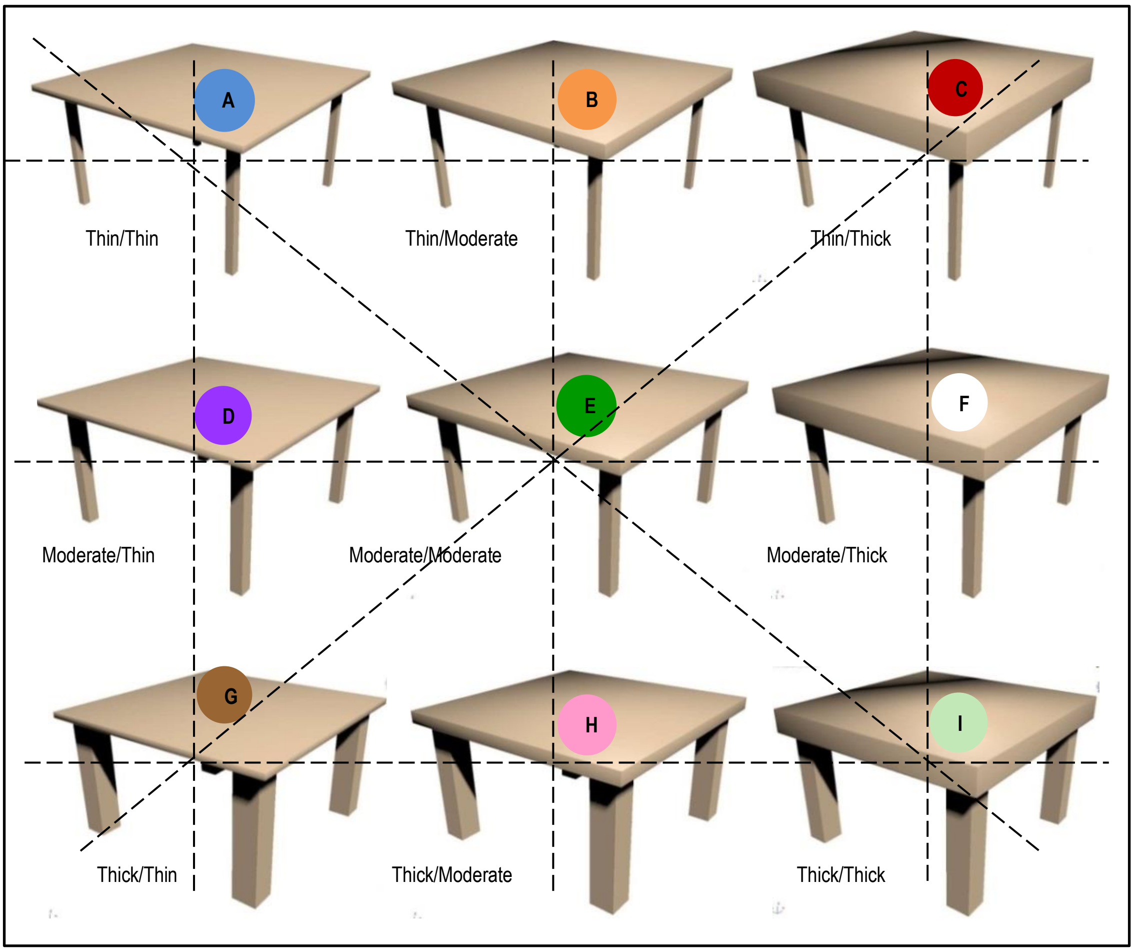


Fig. 3.10 - Table Concepts used in the Exploratory Study

Benefits:

i. The questionnaire could be readily distributed to a large number of participants.

ii. Participants could respond at their own convenience.

iii. Participant anonymity was ensured.

iv. Ethical issues could be minimised.

v. Specific data pertinent to the study could easily be captured.

vi. Survey Gizmo creates automatic reports and outputs the data in a highly usable format, reducing the subsequent time and complexity of analysis.

Drawbacks:

i. Modifications to questions/data requests are not possible once the survey goes live.
ii. Limited guidance is available for participants.
iii. Participants could conceivably misinterpret the instructions and return incomplete or erroneous responses.
iv. Participants undertake the study in whatever environment and manner they choose, potentially leading to inconsistencies or irregularities.
v. It is not possible to benchmark participants' emotional states prior to them undertaking the survey.
vi. Collection of information regarding the respondents' location or ethnic background can be difficult to verify.

The questionnaire consisted of two main sections:

Part 1: Tables were presented individually, one by one in a randomised sequence. Respondents were asked to indicate their emotional responses to each table. Based on the recommendations made following the pilot study, a 5-point Likert scale was used with -2 indicating a very negative response and +2 indicating a very positive response.

Part 2: Respondents were asked to indicate the designs they liked *most* and *least* from the following eight combinations of three tables, *(fig. 12):*

i) ABC, ii) DEF, iii) GHI, iv) ADG, v) BEF, vi) CFI, vii) AEI, viii) GEC

The term 'like least' was used instead of 'dislike' as it was not the intention to imply that the respondents should specifically dislike any of the concepts.

3.6.3.4 Data Collection

The images and questions were uploaded to the internet using 'Survey gizmo': an online questionnaire software package (Appendix H). Respondents were invited to respond via email and social networking sites. Participation was entirely voluntary and anonymous and no personal data was collected. Fifty six usable responses were received and used for data analysis.

On reflection, it could have been useful to record personal information regarding the respondents’ gender, age and ethnicity. However, since no such information was collected it was not possible to further classify the results into sub-categories or seek to identify particular trends within them.

3.7.4 Summary

The exploratory study was devised to test the application of an initial CAD tool prototype based on initial experimentation with the software 3DSMax, while also helping to refine the research question. The study followed analysis of results from the pilot study, but precluded the incorporation of any random element. Instead, the aim of the study was to investigate the types of emotional responses people experienced when appraising a variety of simple CAD concepts for a familiar product type. The study was conducted in the form of an online questionnaire. Null hypotheses were proposed and the objective of the exploratory study was to establish whether these could be proven correct or not.

3.8 Main Study

3.8.1 Introduction

This section describes the main study undertaken to address the research questions formulated following the exploratory study. As well as describing the study itself, this section also provides details regarding the development of the CAD tools used within it.

Further exploration of the potential application of a CAD tool within the conceptual design process was undertaken following the exploratory study. The introduction of randomness in the creation of a design concept's construction geometry was explored. The idea of generating concepts randomly within parametric constraints was considered as a means of creating unexpected and surprising results at the early stages of product design concept creation. This linked with findings from the pilot study and the initial literature review, which both suggested that positive surprise can affect the overall emotional response.

3.8.2 Modification and Expansion of the Research Question

Further development of the table builder CAD tool continued in parallel to the exploratory study. It was envisaged that, whatever the results, a follow-up study would be necessary using a different type of product. Furthermore, in light of comments made during the pilot study with regard to surprises experienced in response to products, investigation had been undertaken into the introduction of unpredictability within the product design concept generation process.

Refinements were made to the initial research question following these developments and analysis of the results of the exploratory study. The refinements included:

i. Consideration of the use of random or seemingly random elements within the concept generation process.
ii. Consideration of the impact of the random element on the experiences of both the designer and the customer (or perceiver).
iii. Differentiation and comparison between like and dislike and strong and weak emotional responses.

A final study was proposed to address the research question (Chapter 1.5) while using a different type of product in an effort to test the findings of the exploratory study. As with the tables used in that study, it was considered preferable to choose a product type that would be familiar to most if not all participants. However, the table concepts used in the exploratory study were predominantly functional and devoid of decoration or detail. For the main study, a product type was sought that would typically be appraised primarily on its aesthetic merits rather than its functional ones.

It was deemed important to keep the design tools simple if participants would be required to interact with the tools. An overcomplicated UI and modelling process could detract from the emphasis of the main study. Two CAD tools were developed, capable of generating design concepts for vases. One tool operated in a similar fashion to the Table Builder tool, with a UI that manipulated the on-screen CAD model in real-time. The other used pseudo-randomly generated variables to simulate the values input by the designer, creating a new concept with each click of a single button.

3.8.3 Aims and Objectives of the Main Study

The main study was primarily devised to investigate whether the emotional responses elicited by pseudo-randomly generated CAD models would differ to those created manually by a designer. The objectives were as follows:

a. To better understand how designers perceive the application of such a CAD tool: Do designers regard a pseudo-random CAD tool as useful in attempting to create product design concepts to elicit emotional responses?
   Null Hypothesis: The designers will not find it useful.
b. To gauge people’s perceptions of the resultant concepts created using the CAD tool: Do people have a preference for product design concepts created using a random or non-random CAD tool? Does the creation method affect the strength or type of emotional responses?
   Null Hypothesis: The concepts will not be regarded differently.

3.8.4 Method

A study was devised in which two groups of participants would be involved in the i) creation, and ii) appraisal of concepts created both randomly and non-randomly. Since the ‘designer’ participants (group A1) would be required to create and select concepts, it was considered preferable for them to have some design experience. Volunteers for the design activity were therefore sought from a final year cohort of BA Industrial Design students at Bournemouth University. These designers were already familiar with 3DS Max and so merely needed a brief overview of each CAD tool and the design exercise.

The study was split into two phases: a Primary phase and a Verification phase. Each phase initially consisted of two parts. The first of these concentrated on the experience of designers during the concept generation process Eight of the nine designer participants in the Primary phase and all nine designer participants in the Verification phase were male. All designer participants were approximately twenty one years of age. Each group of nine participants was from a different cohort of students.

The second part focussed on appraisal of the concepts created by the designers. Two separate groups of participants were asked to select the concepts they liked most and least and the concepts that elicited the strongest and weakest emotional response. With regard to emotional response, the participants were instructed to differentiate between concepts on the basis of those they found most and least provocative or stimulating.

A third ‘comparison’ activity was added at the end of the verification study to directly compare the most popular results of each round of appraisals. For this activity, a group of seventeen participants was asked to report back on like, dislike, SER and WER as well as some specific emotional responses. Each of the three appraisal groups was from a different cohort of students. All appraisal participants were approximately twenty one years of age with a gender split of approximately 75% male and 25% female.

The primary phase was intended to explore whether randomness could play a key role as a concept generation feature within a CAD tool and whether this would result in an augmented design concept capable of eliciting strong emotional responses. In order to test this premise, a design exercise was devised that would engage participants in the design and generation of vase concepts using two CAD tools. The first would facilitate concept creation using interactive controls within a UI to manipulate the concepts' geometric parameters (hereafter referred to as a 'non-random CAD tool'). The other would utilise random functions based on pseudo-random algorithms within 3DSMax to generate the concepts automatically (hereafter referred to as a 'Random CAD tool').

The designer participants' first task would be to create vase concepts using the non-random CAD tool. For the purposes of the study, the designers were asked to create five different concepts. This constraint was applied to provide the designers with sufficient time to become familiar with the CAD tool/interface while keeping the time required and the breadth of choice manageable.

3.8.4.1 Primary Phase: Part 1 – Design Activity

The method for part one (the design activity) was undertaken as follows:

Each designer participant was briefed in the operation of the CAD tool and given a simple brief for the product they were required to design. During the creation of each concept, they were given up to five opportunities to change any aspect of the design before they were asked to stop. The number of opportunities for change was set at five to provide some flexibility without taking too much time. They then set about creating the next four concepts in the same way. Once five concepts had been generated, they were asked to indicate which their favourite was. That concept was then identified for use in Part 2 (Appraisal Activity).

Next, the same participants would be required to create five concepts for the same product using the random CAD tool. The method part two was as follows:

Each designer participant was instructed to create two concepts using the random tool and place them adjacent to each other. They were then asked to compare these concepts, choosing one to keep and one to discard. Next, they created a subsequent concept and compare that to the remainder of the previous comparison, deleting the least liked of that pair. This process continued until ten concepts had been compared, at which point they were instructed to put the last one aside and start again with two new concepts. This whole process was repeated four times until a short list of five concepts remained; the same number of concepts as created with the non-random tool. However, using this approach the five concepts actually represented the outcome of fifty concept comparisons. Again, the participants were asked to indicate which one of the five was their favourite. This concept was also highlighted for use in Part 2 (Appraisal Activity).

Finally, each designer participant was asked to complete a short questionnaire about their experience of using the two CAD tools (Appendix I). The questions centred on the designers' impression of using the CAD tools, what they liked and disliked about them and what they thought of the concepts they had created using them. These questions used a combination of four-point and five-point Likert scales for participants to record their responses, as well as tick and comments boxes. The four point Likert scales were restricted to just two of the question (i.e. those regarding creativity and emotional response), with the removal of the neutral option forcing the designers to make a positive or negative appraisal of their work. This data was collected to help determine whether the design or functionality of the CAD tools might be regarded in any way detrimental to the quality of the concepts they had created.

A total of nine participants volunteered, contributing two concepts each. Images of these were used to form a graphical questionnaire for the next part of the study (Appendix J).

3.8.4.2 Primary Phase: Part 2 – Appraisal Activity

A questionnaire was created by collating images of the selected concepts from part 1 and randomising them in a 6 x 3 matrix (Appendix K). The questionnaires were printed in greyscale on A3 paper and were distributed amongst a group of final year Industrial Design students (Appraisal participants - group B1).

The terms positive and negative emotional response used in the exploratory were replaced with strong and weak emotional response. The findings of the exploratory study suggested that a liked concept was usually indicative of a positive emotional response, and vice versa. It was therefore considered that the *strength* of emotional response combined with a 'like' or 'dislike' appraisal could be more informative. The participants were each asked to indicate the concepts that:

i. They liked most
ii. They liked least
iii. Elicited the strongest emotional response (SER)
iv. Elicited the weakest emotional response (WER)

The two dimensions, when placed on a perception matrix, would show whether the appraisers' preferred concepts elicited strong or weak emotional responses (fig 3.11). While this method would not specifically indicate whether a concept elicited a positive or negative emotional response, a like or dislike response would be considered sufficiently implicit.

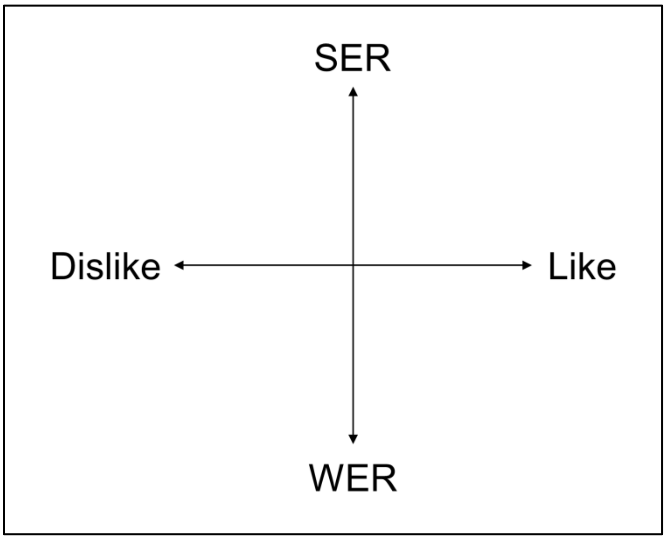


Fig. 3.11 - Appraisal Perception Matrix

The results of these appraisals were collated for preliminary quantitative analysis ahead of the Verification phase. This analysis was intended as a check to highlight any issues or anomalies that might need to be addressed prior to repeating the activities with a second group of participants.

3.8.4.3 Verification Phase: Parts 1 and 2

The Verification phase of the study was intended as a validation of the results from the first and to provide confirmation that the conclusions relating to this aspect of the project were consistent. The verification phase was designed to run in a similar way to the primary phase, utilising:

i) The same CAD tools and questions as the primary phase;
ii) A new group of designer participants (group A2);
iii) A new set of design concepts carried forward to part two.
iv) A new group of appraisal participants (group B2).

Preliminary analysis of the results from the Primary phase prompted a minor alteration to the concept appraisal questionnaire regarding the way the concepts were distributed in the part-2.

In the primary phase, all the concepts were distributed at random in a 6 x 3 matrix on a single A3 sheet (Appendix K). Further to the preliminary analysis that was carried out on the primary phase's data, it became apparent that it might be advantageous to separate the manually and randomly created concepts, and then have the appraiser participants rate the vases from two distinct groups of concepts instead of one. This would mean that a higher count density could be achieved from the same number of participants. The randomly and manually created concepts were grouped on separate pages of the questionnaire and the appraiser participants were asked to select concepts from *both* groups. Other than this, the design and appraisal activities were undertaken, as far as was possible, in the same way as in the Primary phase. There were no significant anomalies or inconsistencies observed.

3.8.4.4 Comparison Activity

In addition to the Verification phase, the most liked concepts from each phase were presented in a final questionnaire (Appendix K) to another, separate group of final year Industrial Design students, to see whether the results from previous appraisal rounds would be corroborated and whether additional information regarding the emotional responses elicited by the concepts would be forthcoming. To that end, the participants were asked to indicate the degree to which each concept elicited certain emotional responses via means of a semantic differential (Osgood, et al., 1957). Three positive emotional responses were used, along with their negative counterparts, in accordance with the pairing of opposing emotions (table 3.4) as described by Desmet (2004).

Unpleasant Surprise	…	Pleasant Surprise
Disgust	…	Desire
Boredom	…	Stimulation

Table 3.4 - Emotional Descriptors for Semantic Differential

Participants were able to select from a 5-point Likert scale, where the neutral option indicated neither emotional response was experienced.

3.8.5 Summary

The main study was devised to test the application of two CAD tool prototypes that resulted from further experimentation with the software 3DSMax following the exploratory study. The study included the incorporation of randomness within one of the CAD tools in an attempt to create unexpected results with the potential to elicit surprise responses. As with the exploratory study, the aim was to investigate the types of emotional responses people experienced when appraising a variety of simple CAD concepts for a familiar product type. However, in addition, the study also investigated the designers' experience of interacting with the tool and creating concepts for appraisal. Null hypotheses were proposed and the objective of the exploratory study was to establish whether these could be proven correct or not while addressing the overall research question. The study was undertaken with the participation of students of BA(Hons) Industrial Design at Bournemouth University.

3.9 Chapter Summary

This chapter described the overall approach adopted to define, refine and answer the research question. It introduced the formulation and initial development of a CAD tool to assist designers in eliciting emotional responses from product design concepts. It discussed the development of the research question and the methodology that was implemented in response. It also outlined the methods that were employed as part of a methodology that was linked to a pragmatist research philosophy.

Along with the literature review, the pilot and exploratory studies provided the theoretical backdrop to the research. The CAD tool's development was undertaken in parallel with the studies and was influenced by the findings at each stage. This culminated in the application of pseudo-random variables. The final, main study was designed to test the application of randomness as a means of augmenting the concept generation process and the emotional responses elicited by those product design concepts.

4. Results and Evaluation

4.1 Introduction

The results of the three studies undertaken as part of this PhD research project are presented in this chapter. The studies are described in chronological order. An appraisal of the each study's implications on the subsequent research direction and focus is provided where appropriate.

The exploratory study was set up to address the initial research question which was formulated following the pilot study. The results of the exploratory study were used to develop the research question further and form the basis for the main study. A short evaluation and summary of the outcomes of the study is provided at the end of this sub-section.

The main study dealt with the expanded research question, which was broken down into five parts. This study consisted of two phases: a Primary phase and a Verification phase. The results of each phase are presented chronologically, prior to an overall evaluation of the data and the study's effectiveness in meeting its objectives. An overall evaluation of each phase is provided in regard to the degree to which the methods served to address the research question.

4.2 Pilot Study

4.2.1 Introduction

The research question leading into the pilot study was:

How do people respond emotionally to images of products that they're encountering for the first time?

This pilot study was qualitative in nature, based around semi-structured interviews with a small sample of participants. The data produced from the study was subjected to a 'thematic analysis', to draw out the key themes embedded within the participants' responses. It was envisaged that those themes would then influence the subsequent direction and emphasis of the research.

4.2.2 Results

Eight female participants were interviewed and asked to describe their emotional responses to a series of product images presented on a computer screen. It was evident that even a relatively simple product could evoke a range of emotional responses. Each interview was fully transcribed and then summarised (Appendix L) before a thematic analysis was undertaken to extract the main themes. This involved the creation and application of 'codes' to data where 'coding' refers to the creation of categories in relation to data. This grouping together of different occurrences of information under a general term enabled individual comments to be regarded as 'of the same type' (fig 4.1). The main themes that arose from the data were as follows:

- Colour – impact on (perceived) environment, aesthetic impact on feelings, stereotypes.
- Form – typicality, semiotics (e.g. perceived: quality; ergonomics; market).
- Function – identification (of function), appraisal of attributes, personal need and values, confusion and surprise (when function not identified).

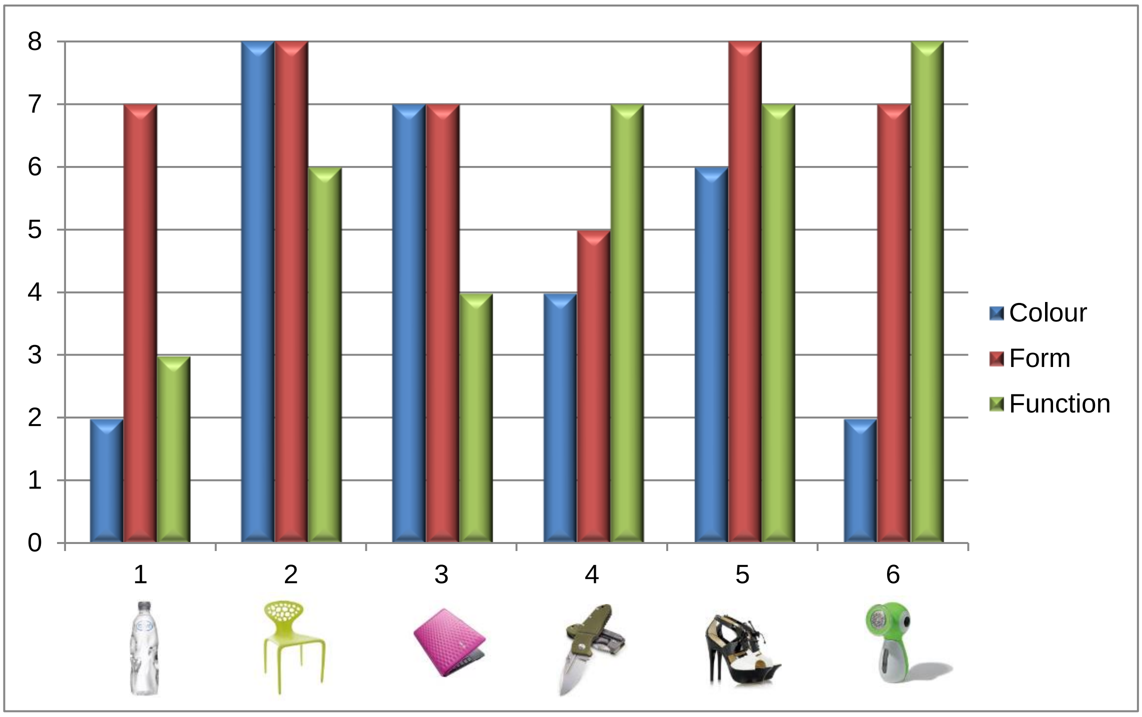


Fig. 4.1 - Occurrences of themes in relation to product images

In addition to the themes occurring directly from the data, the following observations were made in relation to the way the participants responded to questions during the interview:

- Expression of emotions – how people interpret and express their emotional responses at the visceral, behavioural and reflective levels.
- Time – How quickly visual appraisals were made.

4.2.3 Discussion

The themes arising from the data had fairly broad implications. Attempts were therefore made to interpret them within the context of the study, in order to establish their suitability for further research:

- Colour: Often an immediate first impression can be based on colour alone and this was a significant factor for many of the participants in developing an initial 'like/dislike' response. Gender stereotypes were apparent in the way colour had been applied to one or more concepts and these were received with mixed responses.

- Form: Where designs were highly atypical, responses were more polarised in terms of preference. It was evident that participants took cues from aspects of the products' designs when making judgements regarding quality and suitability (for themselves and/or the intended function).

- Function: Participants would often reflect on whether they had any desire for a product before making an assessment of its emotional impact. They were more likely to struggle to articulate an emotional response to a product with which they could not identify a personal need. Products that conveyed controversial inferences appeared to polarise perceptions, but generally resulted in a strong emotional response. For example, most found the high-heeled shoes to be highly appealing while a minority experienced a negative emotional response. Alternatively, the knife's design was highly functional and in a military style, so perceivably quite masculine. Some subjects reported they found it frightening, as if they'd imagined someone using it to perform some threatening or harmful act against them. The fact that the subjects were all female was likely of relevance in both cases. However, although the netbook was one of the most brightly coloured (and potentially gender stereotyped) product examples, the participants generally considered the technical specifications to be more important for a product of that type.

- Unusual products with highly atypical form caused some confusion amongst participants. The Alessi 'Piripicchio' posed a particular challenge for a number of them. This was primarily because participants were unable to determine product function from its appearance, or subsequently whether they had any need or desire for it. However, once the product function was revealed most subjects experienced a surprise response and were then able to make an appraisal. Surprises can be good or bad but can elicit a strong emotional response either way. It was evident that surprise can be a potent means of eliciting an emotional response. However, the nature of the response can be unpredictable. Some of the participants perceived the unexpected or out of the ordinary in a negative way, while others were keen to experience new things.

- Expression of emotions: The ease (or difficulty) with which people were able to describe their initial emotional responses was primarily observed through subjects' physical behaviour during the interviews. While the participants in the study could determine whether they liked/disliked a product based on what they saw relatively easily, some found it much harder to pin-point what it was that made them feel a particular way or why. When attempting to provide a rationale for their responses, participants would often pause to reflect and even struggle to express the specific nature of their emotions verbally. This was somewhat expected as it had been observed in other research of a similar nature (Desmet, 2002). It was also apparent that some people (particularly young people from a non-design background) found it difficult to articulate the source of their emotional responses in any real detail (i.e. a connotation or association resulting from the product's aesthetics).

- Time: The participants were given a short moment to appraise each product image before being asked to comment. In almost all cases, the participants were ready to provide their appraisals without further delay. Where the function was not immediately obvious (as in the case of the clothes shaver) it took longer as the participants spent that initial time attempting to identify what the product was.

The findings of the pilot study demonstrated that the *specific* positive or negative emotional responses experienced in relation to the same product could differ significantly. All the products chosen were commercially successful examples from established designers. It should therefore have been unlikely that any of the products would be perceived in an overwhelmingly negative way as a result of poor design. However, the deliberately provocative nature of the products and the openly subjective nature of the appraisals meant that it was somewhat inevitable that a range of emotional responses would be observed. Colour was a strong emotional motivator and had the potential to be an overwhelming factor when appraising a product. While colour preference was not of particular interest to this study, it was useful to observe the strength of emotional response that it could elicit.

It was indicated that surprise can be an emotional augmentation factor, both in a positive and negative way. Typicality can play a key role in the nature and intensity of surprises associated with first contact responses (Hekkert, et al., 2003). A highly atypical design is more likely to generate a stronger reaction. Initial responses to the unexpected may vary depending on:

a. The nature of the surprise;
b. What the person being surprised is anticipating;
c. Whether the surprise exceeds the person's expectations;
d. Whether the surprising element provides some additional value;
e. The context within which the surprise is experienced;
f. The extent to which the surprising or unexpected element dominates (or is overshadowed by) other features;

g. Whether there are other design attributes that combine with the surprising element in some way to produce an augmented positive or negative affect;
h. Whether the person enjoys experiencing the sensation of surprise.

With advances in technology, the maxim that ‘form follows function’ has become less reliable (Objectified, 2009). However, not being able to identify a product’s function can cause frustration and (in some cases) contribute to a feeling of embarrassment. People generally dislike being confused and this can extend to being unable to work out what something is or how it works. There is a danger that the person appraising the product in question will lose interest or that the initial dislike will lead to a negative perception in the longer term. This may be exacerbated if such a failure challenges one’s self-concept that they are savvy, intelligent or well informed (Shavelson & Bolus, 1982). Hence, for some of the participants, the confusion associated with not understanding what they were seeing elicited a negative emotional response. Others found it intriguing and were motivated to solve what they perceived as a problem, curious to know more about what the product might do and why it might have looked as it did. The revelation of a product’s function or the solution of a visual conundrum can eventually lead to a surprise emotional response, which, as previously discussed, may be positive or negative as result of the overall experience.

It was evident that subjects tended to reflect upon individual paradigms and personal experiences when making an appraisal, sometimes with recurring themes. The pilot study demonstrated how the initial (visceral) emotional responses elicited by products can be influenced by the subsequent behavioural and reflective levels. Ahead of the pilot study, the assumption had been that the first contact experiences would demonstrate the visceral level of emotional processing proposed by Norman (2004). However it was clear that as the participants began explaining their response to each product that they were reflecting on the source of their feelings, often attributing them to their families or up-bringing. The individual’s paradigms and self-concept were apparently highly influential when attempting to provide a rationale for their response. For example, some people enjoy being controversial while other, more conservative, individuals prefer to avoid controversy and may even be prone to taking personal offence from it. Although the participants were able to examine the product images for as long as they wanted, there was little opportunity to experience the products at the behavioural level (i.e. the products were not physically present and could not be touched or held).

4.2.4 Observations and Limitations

A number of observations were made during the course of the pilot study. These were summarised for interpretation and taken into consideration when planning subsequent studies:

- **The effect of colour in subsequent studies.** Colour can be divisive, with various cultural associations (e.g. political parties and sports teams), gender stereotypes (e.g. pink for girls and blue for boys) and semiotic sub-texts (e.g. Khaki to signify military applications or red to signify danger).
- **Terms used when collecting emotional responses.** People who are unaccustomed to talking about emotions (particularly in response to design) can struggle to articulate the nature and intensity of their responses accurately. Furthermore, the same type of response can be reported differently by different people. As a result, it is preferable to use simple terms to describe positive or negative responses (e.g. 'like' or 'dislike', 'positive/negative' emotional response).
- **Presentation medium.** 2D representations of 3D form were found to be an appropriate means of eliciting emotional responses. The participants found the images presented on the computer monitor provided sufficient stimuli despite the physical limitations this imposed (i.e. touch, physical interaction and manipulation).
- **Typicality and emotional responses.** Typicality and surprise can have an effect on emotional response. Creating design concepts that produce pleasantly surprising experiences is an appealing prospect for many designers (Ludden, et al., 2006) and can be used to create pleasurable user experiences.

- **Gender preference.** Consideration should be given to whether there is any gender bias exhibited between respondents and whether this indicates divisive features of aesthetic trends.

It is acknowledged that the scope of the results is limited by the context of the study and the sample of participants. The following limitations were considered when interpreting the data:

i. Familiarity

While it was preferable that participants were unfamiliar with the specific products on show, it was somewhat inevitable that some would have seen one or more of the products previously. In these cases, the participants were asked, where possible, to reflect upon their first impressions. While in most cases they were able to do so with apparent ease, the physical moment in which that visceral response would have occurred had already passed. As a result, it cannot be confirmed whether the memory of that visceral emotional response had not been diminished or augmented over time.

ii. Presentation medium

For reasons of practicality and consistency, the products were presented as high definition images on a good quality computer screen. However, this medium could be regarded as a somewhat inferior substitute for actual physical examples of the products. Had the actual products been to hand, additional themes relating to tactile and functional responses might have been forthcoming, as well as responses to aspects of the products that were not visible in the images provided.

iii. Sample size and representation

The number of interviews and the range of subjects interviewed were constrained. All subjects were British, female and aged between eighteen and twenty five. As such, although the study was considered effective, it cannot be regarded as extensive.

4.2.5 Summary

The pilot study investigated the emotional responses people experienced when encountering a product design for the first time. It was evident that where the type of product was familiar an individual was able to make an appraisal based on a combination of the visual information presented and reflection based on the individual's prior experiences and beliefs. Where a new product design met or exceeded one's expectations a positive emotional response was typically experienced. Conversely, when the new design failed to meet their expectations or needs, a neutral or negative response was more likely. On the whole it was found that the immediate, visceral response was far less influential than the behavioural and reflective responses in these cases.

However, where the product type was unfamiliar or unrecognisable, the visceral response was found to be slightly more significant. In these cases, the individual's immediate attention was diverted towards identification of the object rather than whether it appeared attractive or useful. Once the product's purpose was eventually identified or revealed, the appraisal could continue as normal. When the revelation led to surprise, the emotional response that followed was apparently (as observed by the interviewer) slightly stronger, as a result of either delight or disappointment. It was of particular interest to the onward direction of this research project that surprise could be influential in producing an augmented positive emotional response, making an initial encounter more memorable.

4.3 Exploratory Study

4.3.1 Introduction

The custom built CAD tool called 'Table Builder' was initially created as a test-bed for the development of a CAD tool aimed at designers working within a 3D digital domain. It was envisaged that the provision of such a tool might provide creative stimuli for designers during the concept development phase of the design process, rather than for creating a final concept or detailed design. An exploratory study was proposed, consistent with the pragmatist methodology, to gain further insight of the research problem and refine the research question. The objectives of the study were to:

- Evaluate the effectiveness of the (Table Builder) CAD tool as a means of generating affective product concepts.
- Establish an appropriate means of data collection with regards to aesthetic preference.

Unlike the pilot study, the exploratory study used CAD rendered images instead of photographs of actual products. The images were of simple table designs, created in 3DSMax using the custom made 'Table Builder' CAD tool. These were incorporated into an electronic questionnaire consisting of CAD images of a range of table proportions. The questionnaire was split into two parts. Part one asked respondents to indicate their emotional responses (via 5-point Likert scale) to each of nine table concepts in a randomised sequence. Part two required respondents to indicate the designs they liked *most* and *least* from eight combinations of three table concepts. The questionnaires were distributed via the internet.

56 participants responded to the study. Age and gender were not recorded. The results of part one (Q1-9) and part two (Q10-25) are presented in Appendix M in the form of pie charts. An evaluation of the results is provided in the following section, together with a discussion of the findings.

4.3.2 Results

The data was initially analysed to identify the most and least popular table concepts in terms of emotional response. Fig 4.2 indicates the breakdown of positive, neutral and negative responses to the nine table concepts. This serves to illustrate how table concepts E and I both received similar numbers of each response while table concepts B and C (for example) were more clearly differentiated.

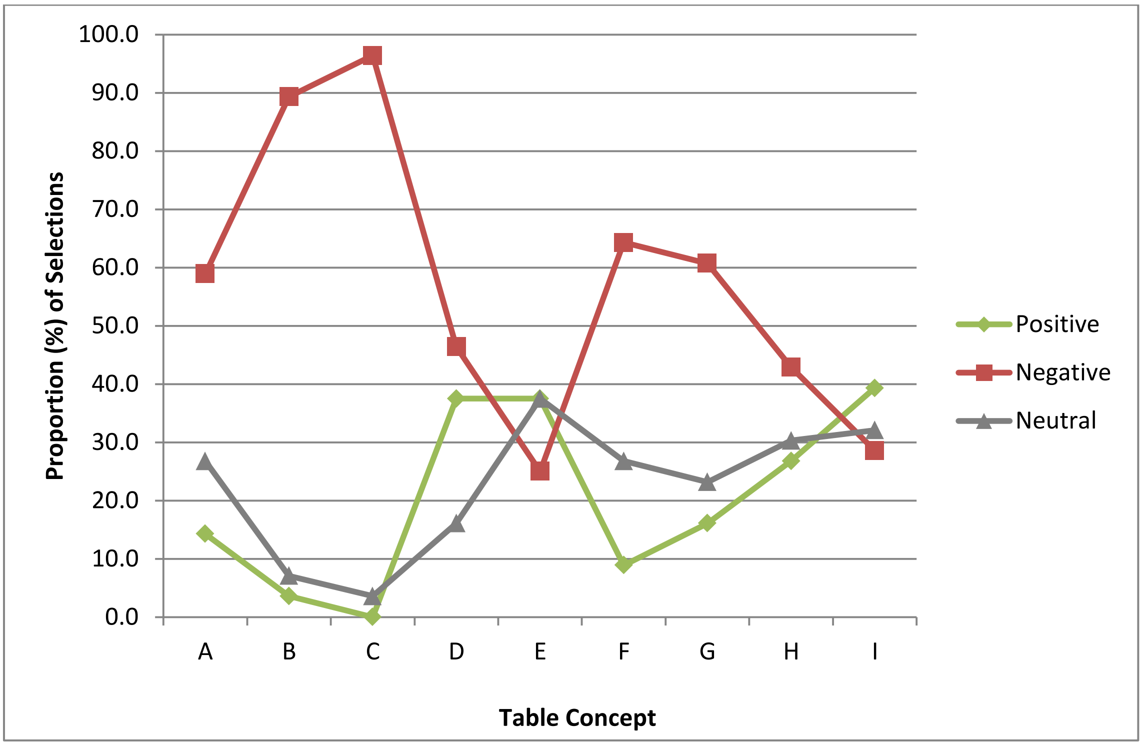


Fig 4.2 – Breakdown of Emotional Responses to Table Concepts A to I

The data was then subjected to a number of tests in an effort to best answer the first of the research questions. These included:

- Identification of median and mode values and Inter Quartile Range (IQR).
- Relative positioning of each concept from the mean average.
- A comparison of the liked most / disliked least and liked least /disliked most concepts.

The data was examined with a view to gaining an overall indication of emotional responses to each table concept. To that end, the median and mode averages were calculated, as shown in fig 4.3. For consistency, the data range used in the study (i.e. -2 to +2) is maintained. However, for IQR calculations, those values have been converted (i.e. -2=1, -1=2, 0=3, 1=4, 2=5) so that the highest possible IQR value would be 5 and the lowest is 0.

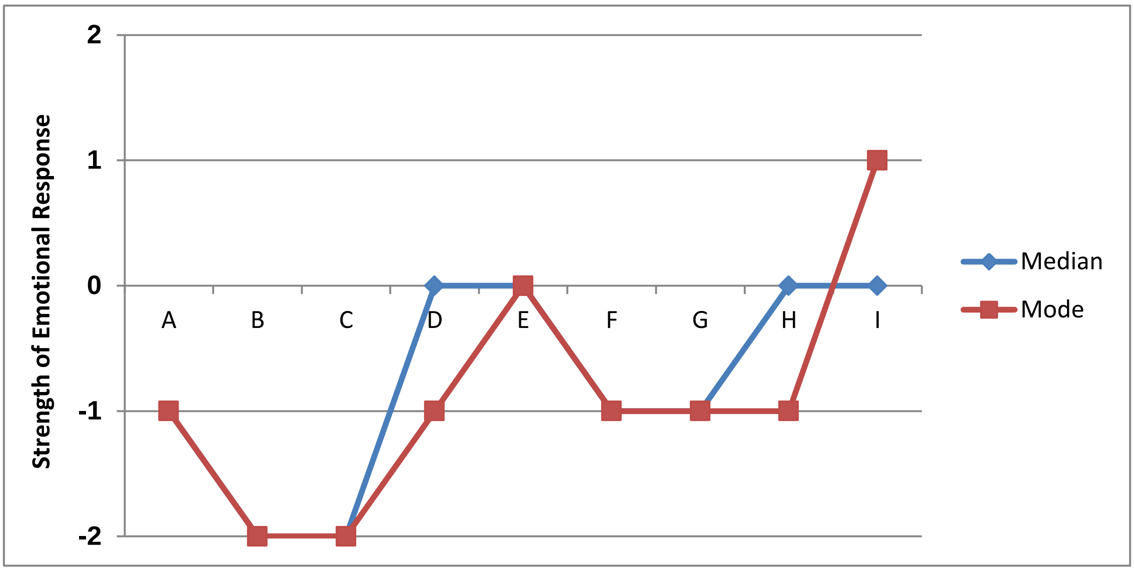


Fig 4.3 - Average Emotional Responses to Table Concepts A to I

Table concept I (Mode= 1, Mdn = 0, IQR=2) was the only concept to receive a positive overall response, and only then when calculated using the mode. Two other table concepts: D (Mode = -1, Mdn= 0, IQR = 2); and H (Mode = -1, Mdn = 0, IQR = 2) were also found to have different mode and median values, although in both these cases the mode was lower than the median. In total, four concepts had an IQR>1, the other being Table concept E (Mode = 0, Mdn= 0, IQR = 2). The higher IQR in these cases is indicative of the polarisation of the emotional responses they were reported to elicit. All four received significant proportions of both positive and negative emotional responses (i.e. 25% or higher of each).

As a comparison between concepts, cumulative emotional response values were derived from the results of part 1 to indicate relative positions between concepts (fig 4.4). Relative positions were achieved by combining all the negative responses and subtracting this value from the total of all the positive responses. Neutral responses were ignored for the purposes of this test.

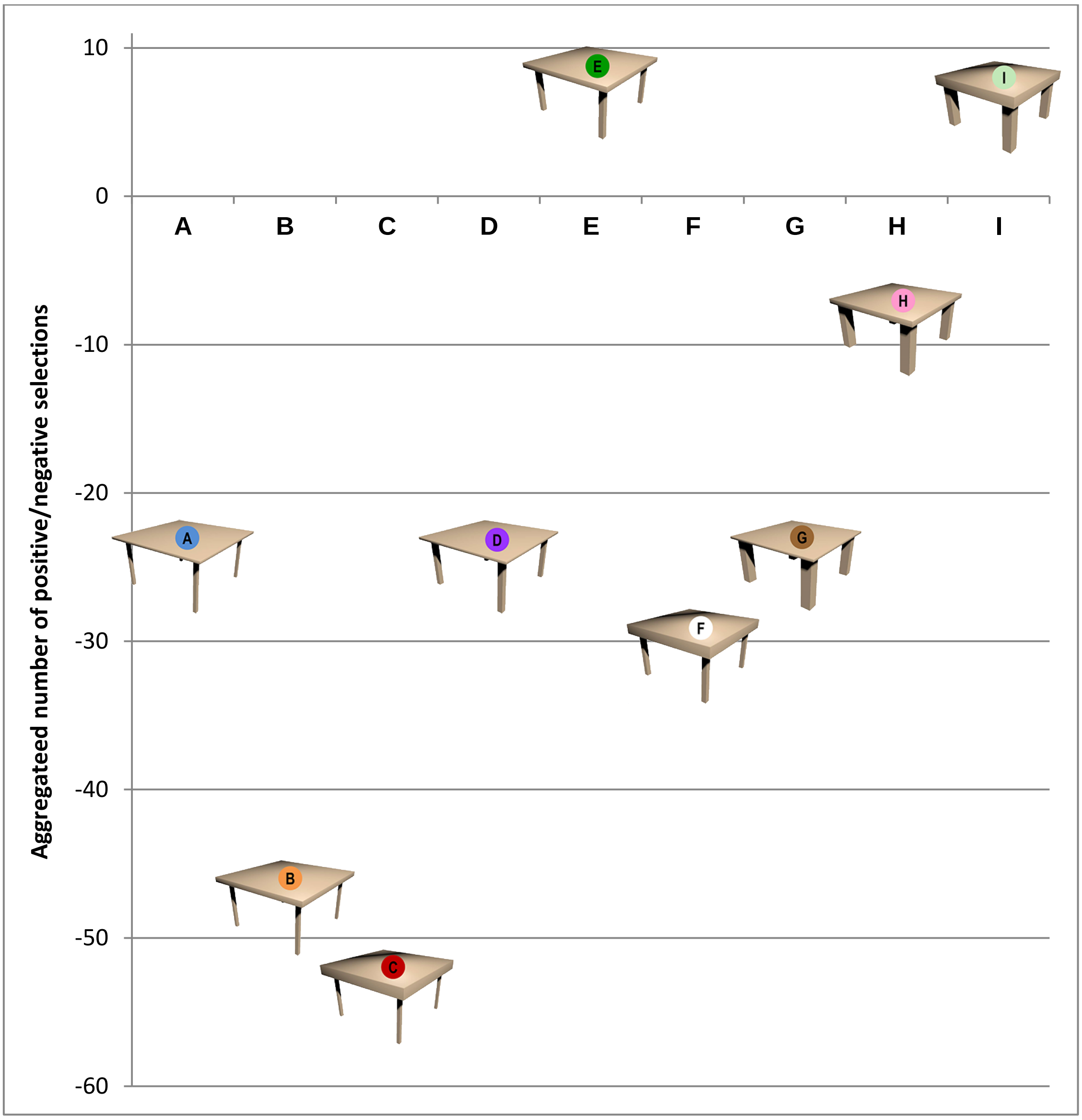


Fig 4.4 - Relative Emotional Responses to Tables A to I

The following additional insight was provided by these results:

- Table concepts E and I elicited the highest proportion of positive emotional responses, i.e. >25% of emotional responses they elicited were positive.
- Table concept C elicited the highest proportion of negative emotional responses, i.e. >96% of emotional responses it elicited were negative (with zero positive responses).

- All the table concepts elicited a significant number of negative emotional responses, i.e. =>25% of emotional responses they elicited were negative.

The following was evident from the overall data:

i) There were more very negative emotional responses than very positive ones.

ii) There were as many very negative emotional responses as neutral ones.

iii) The majority of emotional responses were negative.

iv) None of the table concepts elicited a particularly noteworthy number of ‘very positive’ emotional responses.

v) Table concepts B and C elicited a high number of ‘very negative’ emotional responses but very few (if any) positive responses.

vi) Table concepts D, E and I elicited the highest number of positive emotional responses, but also a significant number of negative responses.

vii) Table concept D elicited as many positive emotional responses as Table concept E, but overall elicited more negative responses than it did positive ones.

viii) Table concepts E and I elicited almost as many neutral responses as they did positive responses.

ix) A proportional breakdown of emotional responses recorded by the 56 respondents (fig 4.5) indicates that overall the emotional responses were predominantly negative or neutral.

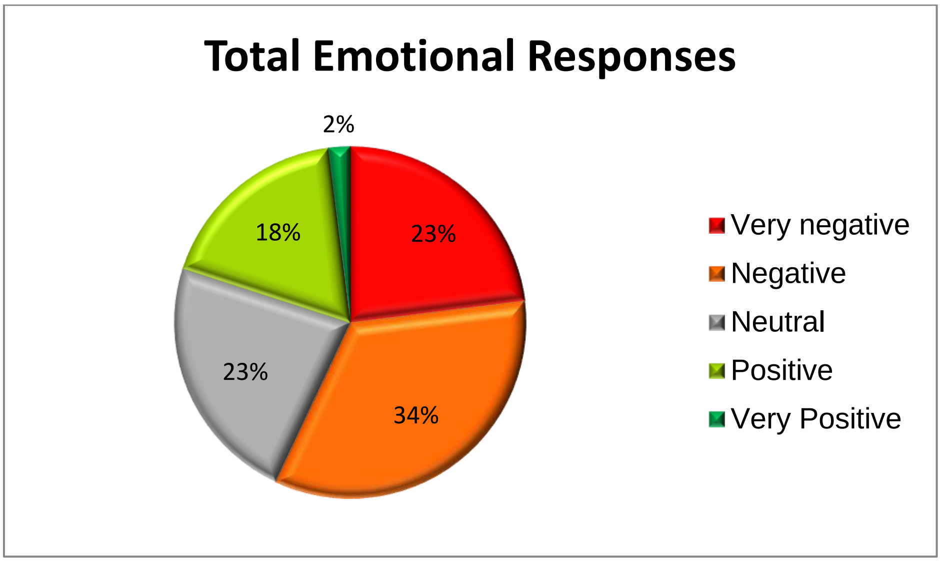


Fig 4.5 – Overall Summary of Emotional Responses to All Table Concepts

The perception matrix in fig. 4.6 represents the cumulative results of part 2 of the exploratory study. The pie charts in the right-hand quadrants indicate the relative proportions of selections made by the participants in response to questions 10 to 25, while the pie charts on the left represent the cumulative values of the table concepts that were least selected. It was hypothesised that the design concepts selected least often (i.e. for like and dislike) ought to be the opposite of those selected most often, and vice versa. On the whole, fig 4.5 indicates that the selected and inferred concepts were similar. Table concept E was the most moderate of all the table designs as it had both medium thickness top and legs. It is therefore not surprising that it was one of the most liked tables and by far the least disliked. Likewise, Table concept C was both the least liked and most disliked concept. This concept also elicited the greatest number of negative emotional responses in part 1 of the questionnaire. However, there were notable exceptions to this hypothesis. Table concept I, which was one of the most liked table concepts, did not feature in the least-disliked quadrant at all. This was mainly due to other concepts in the same comparisons being selected as 'liked least' marginally less.

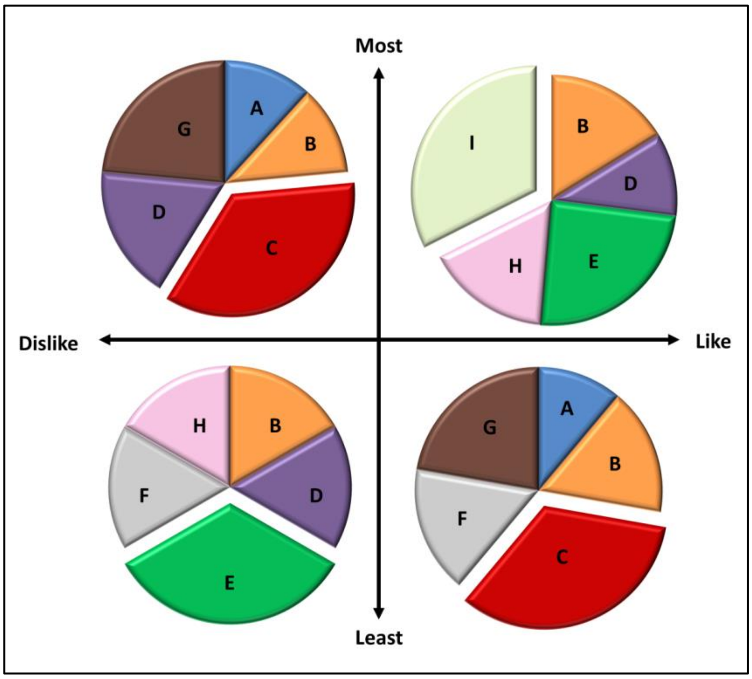


Fig 4.6 - Perception Matrix Illustrating Results of Exploratory Study Part 2

Other anomalies include Table concept F, which appears in both the ‘disliked least’ and ‘liked least’ quadrants of fig 4.4, while Table concept B appears in all four quadrants. Fig 4.6 shows the effect of combining the results of all four quadrants to achieve an overall level of preference in relation to each concept. A concept scoring 1 here would mean it was both the most liked and least disliked in every comparison, while a score of -1 would indicate the concept was the least liked and most disliked. It can be seen from this chart that the positions of tables B and F in the perception matrix have the effect of cancelling each other out. As a net result, these concepts appear to be regarded as neutral. At the same time it can be seen that, although Table concept I was liked more than Table concept E in their direct comparison, the greater number of inferred ‘disliked least’ selections means that Table concept E comes out as the strongest (i.e. most positively received) concept overall.

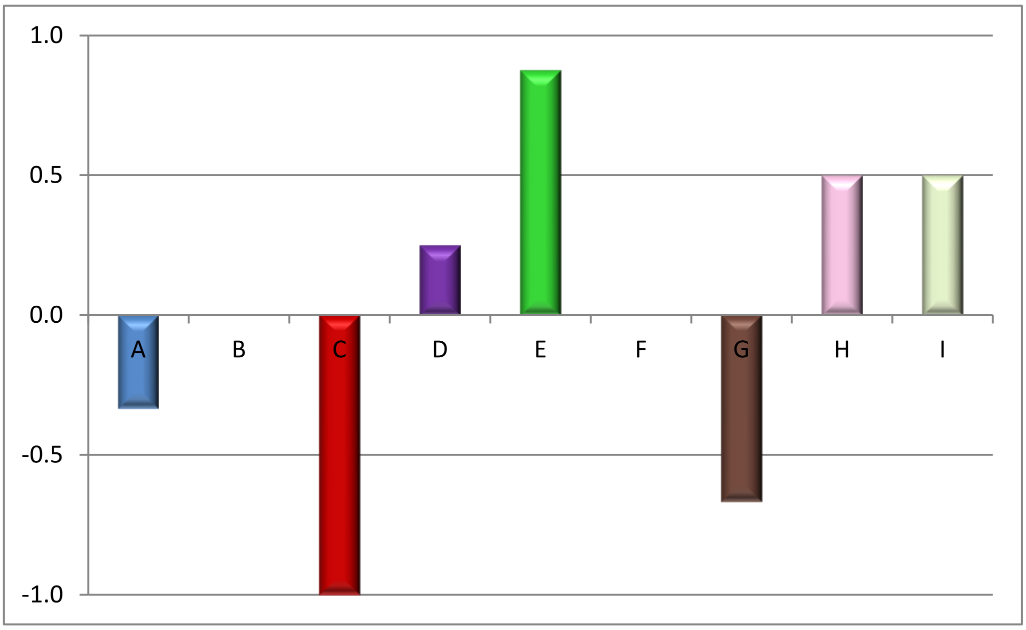


Fig 4.7 - Overall Perceived Strength and Polarity of Table Preferences

4.3.3 Discussion

An objective of the exploratory study was to establish an appropriate means of data collection with regards to aesthetic preference. The questionnaire was created using the online software known as 'SurveyGizmo'. The questionnaire format was generally considered successful in recording consistent results. Links to the electronic questionnaire were distributed via the internet and responses were collated automatically by the software. This online distribution method meant that respondents were able to participate with minimal inconvenience. However it also meant that environmental conditions with a potential bearing on the respondents' emotional state (such as noise, temperature and distractions) could not be controlled or monitored.

A Fleiss' kappa inter-reliability test was performed on the data (Appendix N). It was observed from the results that participants were somewhat inconsistent when asked to identify positive or negative emotional responses in relation to concepts presented in isolation of each other. With a 5-point Likert scale the emotional responses to the nine concepts in part 1 were quite varied (K=0.12) and converting the scale to 3-point only provided relatively minor improvements (K=0.13). However, the results of part 2 suggested that 'like' and 'dislike' responses to each of the designs were quite consistent across the sample (K=0.52), indicating that consistency is improved when participants are provided with a range of concepts from which to compare, rather than concepts in isolation. This insight should inform refinements made to the research method going forwards. In particular, these include provision for participants to compare concepts directly, rather than rate them in isolation of one another.

An additional objective of the exploratory study was to evaluate the effectiveness of the (Table Builder) CAD tool as a means of generating affective product concepts. In terms of generating a large breadth of incrementally similar concepts in a short space of time, the tool could be considered as effective. The concepts were created quickly and easily using the tool and they were amongst the simplest feasible designs. For the table concepts selected for the exploratory study, none of the modifiers incorporated into the Table Builder CAD tool were used. The form of each concept was therefore directly determined by the designer’s choice of proportions. A far broader range of concepts could conceivably have been tested had the available modifiers within the tool been employed. It is not possible to determine from this how a different selection of concepts might have performed, however it is conceivable that the approach adopted for the exploratory study could be adapted to identify those concepts capable of eliciting a higher proportion of positive emotional responses.

4.3.4 Observations and Limitations

i. Presentation medium and rendering

This was an online questionnaire, so the products were viewed as images on participants’ own personal computer hardware. This could conceivably include tablets and mobile phones. The size and quality of the display hardware and the way it represented the concepts cannot be assured.

While every effort was made to ensure all tables were presented in an identical way, the slight differences in proportion did have a minor effect on the shadows and lighting applied by the CAD software.

ii. Questionnaire completion time

Since the questionnaire was distributed over the internet, there was no way to ensure that participants spent the same length of time answering the questions.

iii. Participant Inter-rater reliability

An inter-rater reliability test was used to assess the consistency of the participants' responses. Fleiss' kappa was adopted as it seemed most suited for use with multiple appraisers. However, while guidelines exist, there is no generally agreed measure of significance for values of k. The two parts of the study were tested. For the results of part one, k=0.12 which, while fairly low, typically indicates slight agreement across a sample. The data collected from part two indicated good inter-rater reliability, with a Fleiss Kappa value of k=0.59. (Appendix N).

iv. Typicality of table concepts

It was observed that table designs of typical, average proportions (e.g. medium top/legs) were liked more than atypical ones (e.g. thick top with thin legs). An internet search indicated that the proportions of the most popular table concepts were fairly typical of contemporary table designs. Table designs that appeared strong and durable (e.g. thick top with thick legs) were liked more than those that appeared weak or fragile (e.g. thin top with thin legs). Both these findings suggest that the images of the products provided 'affective artefacts' that perceivers could use during the appraisal process to determine fitness for purpose (Spillers, 2004). This also corresponds with Tiger's four pleasure framework (Tiger, 1992) which suggests that when someone appraises a product they make an assessment of its suitability and desirability on a number of levels. According to Norman, this type of processing takes place at a reflective level (Norman, 2004) through imagined scenarios informed by memories of past experiences. A product that, even at a superficial level, does not meet one's expectations of fitness for purpose will therefore likely be rejected or at least deemed undesirable as a result.

4.3.5 Summary

The results of the exploratory study were found to refute the first null hypothesis (i.e. The responses should not differ significantly), since the emotional responses varied considerably in relation to the different table design concepts. It was evident from the results that the majority of table concepts presented in the questionnaire were perceived to elicit a negative emotional response. However, despite this, there was a clear distinction between the top and bottom concepts.

The positive and negative emotional responses generally corresponded with the most liked and most disliked concepts. Therefore the second null hypothesis (i.e. the factors are *not* independent of each other) was upheld. In the main there was a link evident between preference and emotional response, albeit more so for the strongest and weakest concepts than the intermediate ones.

The geometric proportion was the only major differentiator between the table concepts presented. Therefore, it is fair to say that the geometric proportions had a significant impact on the emotional responses they elicited, refuting the last null hypothesis (i.e. Geometric proportion alone does not significantly affect the emotional responses elicited by the concepts).

Overall, the exploratory study demonstrated that the CAD tool was a feasible means of generating affective product concepts. In addition, it was found that the concepts did elicit a range of positive and negative emotional responses, despite differing only by geometric proportion and being appraised using simple 3D CAD representations. The results would also seem to indicate that appraisals were made in line with the designer's expectations in terms of fitness for purpose and usability (Crozier, 1994), (Jordan, 2002).

4.4 Main Study

4.4.1 Introduction

It was anticipated that the findings of the main study would help to answer the primary and secondary research question (Chapter 1.5). Undergraduate Industrial Design students from Bournemouth University participated in the study, in which two CAD tools were used to create design concepts for vases. In the primary phase of the study, a group of students took the role of designers to generate design concepts (Group A1) before another group (Group B1) appraised those concepts. Following some preliminary analysis and minor modifications, a verification study was undertaken in an effort to ensure rigour and reliability of results. The designer and appraiser groups in the both phases were similar in size and composition. Those groups in the verification phase are referred to as A2 and B2. The final outcomes were compared to identify discrepancies or irregularities before drawing conclusions.

4.4.2 Primary Phase: Part 1 (Design Activity) Results

Each 'designer' participant completed a short questionnaire that summarised their experiences after using the CAD tools. They were asked to indicate their overall impressions of interacting with the CAD tools and to identify what they liked or disliked. They were then asked to offer their opinions of the concepts they had created using the tools; in terms of originality, like/dislike (using a 5-point Likert scale), creativity and the extent to which they considered their concept might elicit an emotional response (using a 4-point Likert scale).

With regards to designer interaction, 100% of participants indicated that their impression of using both CAD tools had been positive, scoring 4 or above on a 5-point Likert scale where 1 = very bad and 5 = very good (fig 4.8).

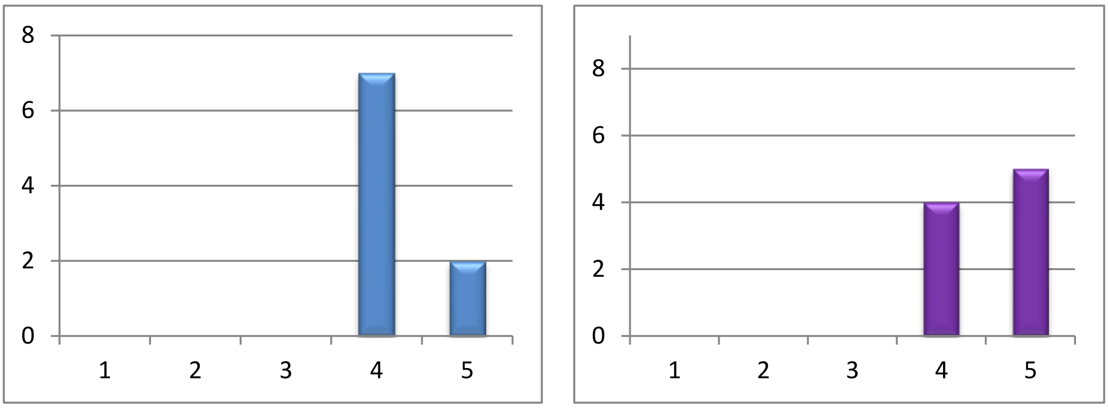


Fig 4.8 - Primary Phase Q1: Overall impressions from the CAD tool interaction
(Left: Non-random CAD tool, Right: Random CAD tool)

The designers also all indicated that they liked the speed of both tools. However, fewer participants liked the random CAD tool's control interface and feedback (fig 4.9). One participant commented that they thought the non-random CAD tool was unique and that it could change the "concepting" (i.e. concept generation) process.

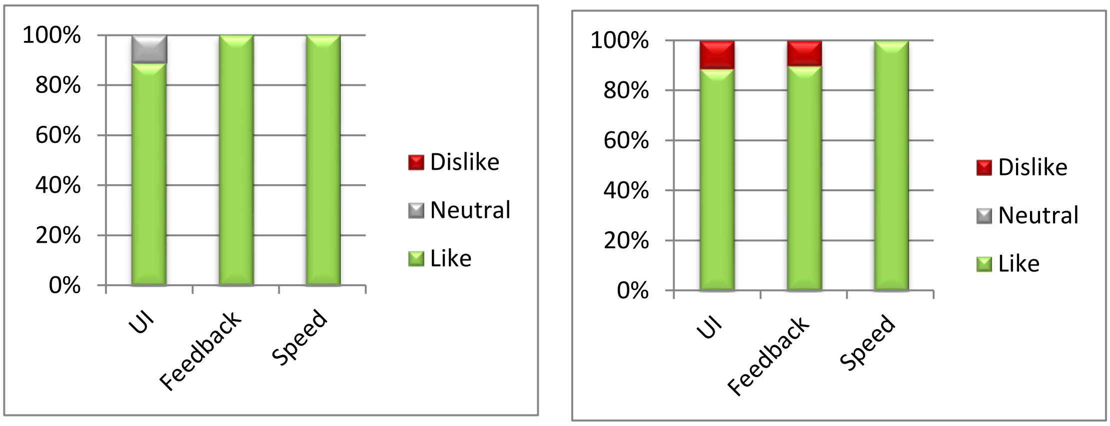


Fig 4.9 - Primary Phase Q2. Likes and dislikes from the CAD tool interaction
(Left: Non-random CAD tool, Right: Random CAD tool)

The majority of participants indicated that they liked the concepts they created using both CAD tools, scoring point 4 or above on a 5-point Likert scale where 1 = dislike a lot and 5 = like a lot (fig 4.10), although the results for the random CAD tool were generally a little higher.

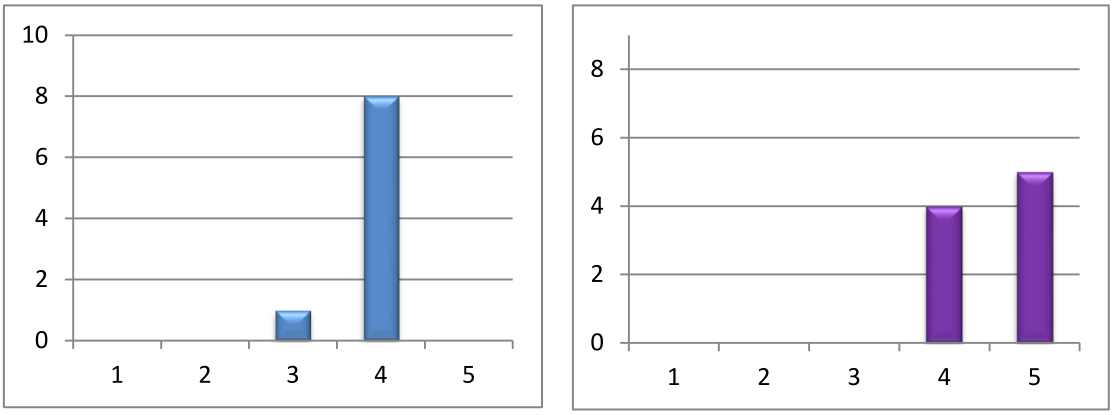


Fig 4.10 - Primary Phase Q3. Extent to which designers liked the concept they created
(Left: Non-random CAD tool, Right: Random CAD tool)

Five participants considered their manually created concepts to be original, scoring point 4 or above on a 5-point Likert scale where 1 = very unoriginal and 5 = very original (fig 4.11). Seven considered their randomly created concepts original.

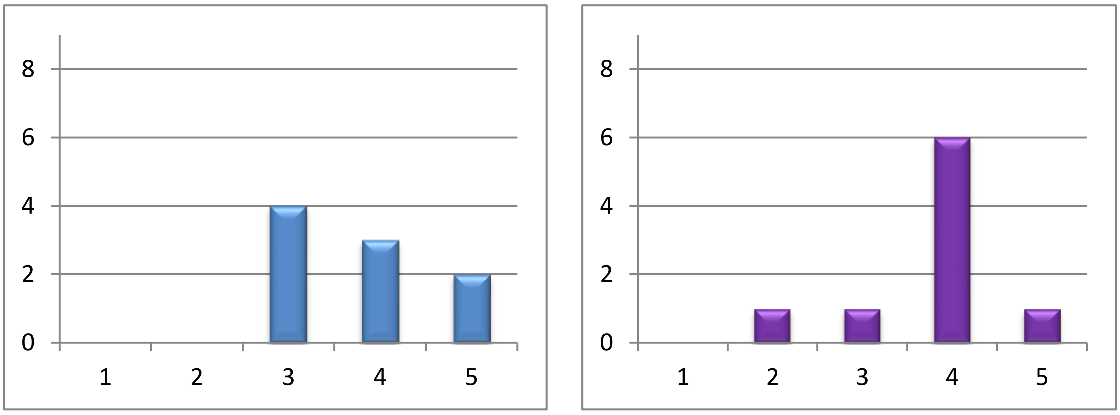


Fig. 4.11 - Primary Phase Q4. Extent to which designers considered their concept original
(Left: Non-random CAD tool, Right: Random CAD tool)

Six participants considered their manually created concepts to be significantly surprising or better, rated 3 or above on a 4-point scale where 1= no surprise, 2 = little surprise, 3 = significant surprise and 4 = highly surprising (fig 4.12). Five considered their randomly created concepts to be at least significantly surprising.

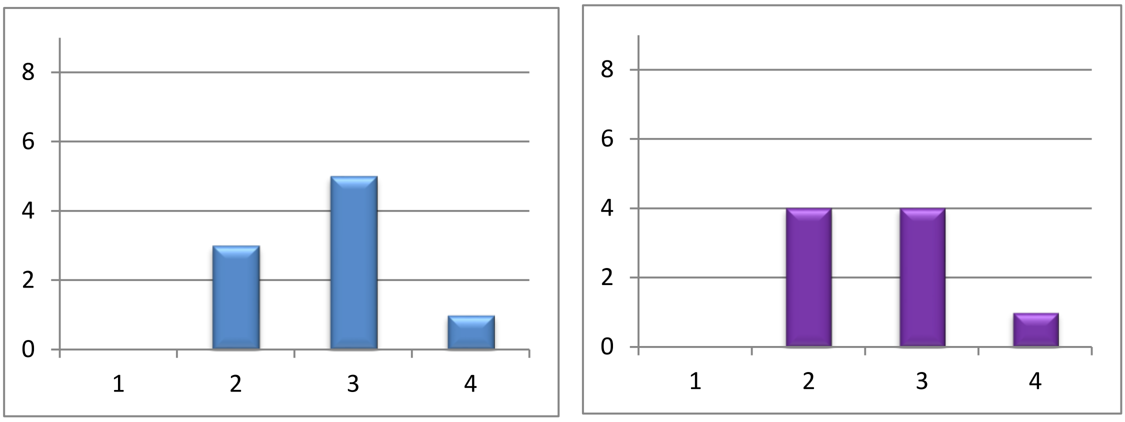


Fig 4.12 - Primary Phase Q5. Extent to which designers considered their concept surprising (Left: Non-random CAD tool, Right: Random CAD tool)

Seven participants thought their manually created concepts elicited a significant or emotional response or higher, rated 3 or above on a 4-point scale where 1 = no emotion, 2 = little emotion, 3 = significant emotion and 4 = high emotion (fig 4.13). The same was true for the randomly created concepts.

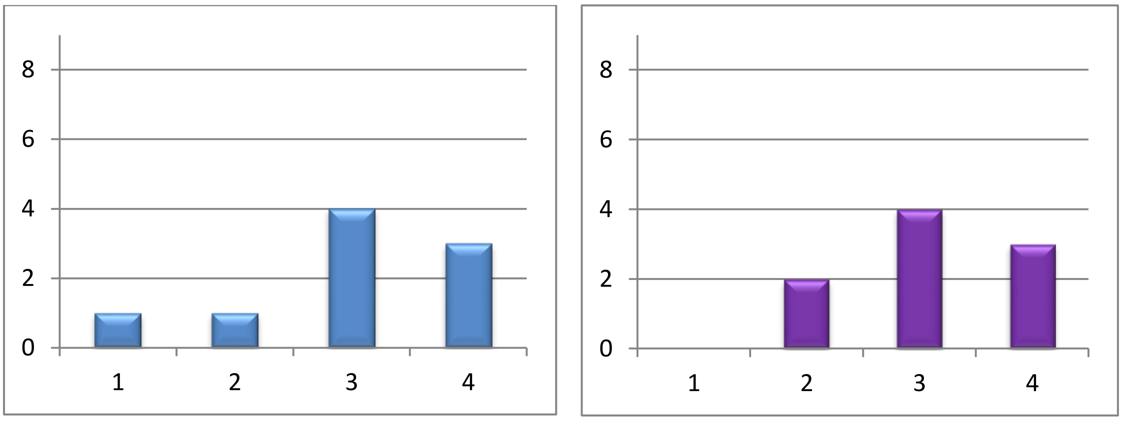


Fig 4.13 - Primary Phase Q6. Extent to which designers considered their concept elicited an emotional response (Left: Non-random CAD tool, Right: Random CAD tool)

4.4.3 Primary Phase - Part 2 (Appraisal Activity) Results

Group B1's responses to the concepts created by group A1 were collected and collated for analysis as follows:

- Cumulative values of liked-most/liked-least were calculated (i.e. the total liked-most responses for each concept, minus the liked-least responses for that concept).

- Cumulative values of SER/WER were calculated (i.e. the total SER responses for each concept, minus the WER responses for that concept).
- Overall aggregate values for liked-most/like-least and SER/WER were calculated for the non-randomly and randomly created concepts.

These values were analysed with the following objectives:

- To ascertain whether there was a relationship between the concept that was liked-most and the concept that elicited the SER.
- To ascertain whether there was a relationship between the concept that was liked-least and the concept that elicited the WER.
- To identify any concepts that were liked-most while eliciting a WER, or liked-least while eliciting a SER.
- To ascertain whether there was a correlation between preference, emotional response and/or method of concept generation (i.e. random or non-random).

The product design concepts created by each tool were categorised for identification in the form P# v1/2 a/b, See Table 4.1 for key.

P#	Participant number (1-9)
v1/2	Concept generation method : 1 = non-random, 2 = random
a/b	Study phase: a = primary phase , b = verification phase

Table 4.1 - Key to vase concept codes

4.4.3.1 Data Analysis

The cumulative results of the primary phase are presented on the perception matrix in fig. 4.14. This indicates that a high density of concepts occurs around the neutral points on the axes suggesting that those concepts either received few selections, or the number of positive and negative selections largely cancelled each other out. Those concepts that occur furthest from the neutral axes can be considered of greater significance. Concept P2v1a was evidently the strongest in terms of preference and emotional response, appearing in the top-right corner of the matrix. Concept P7v2a received almost as many liked-most selections but considerably fewer SER selections.

In contrast, concept P8v1a was the weakest concept, placed in the bottom-left quadrant of the perception matrix. Concept P9v2a received even more WER selections but appears relatively neutral regarding preference due to the cancelling effect of its liked most and liked least selections. Concept P7v1a received the second highest number of SER selections but was also fairly neutral for preference with no liked most selections. Concept P3v1a was the second least liked concept while receiving a significant portion of the SER selections. None of the most liked concepts received a very high number of WER selections.

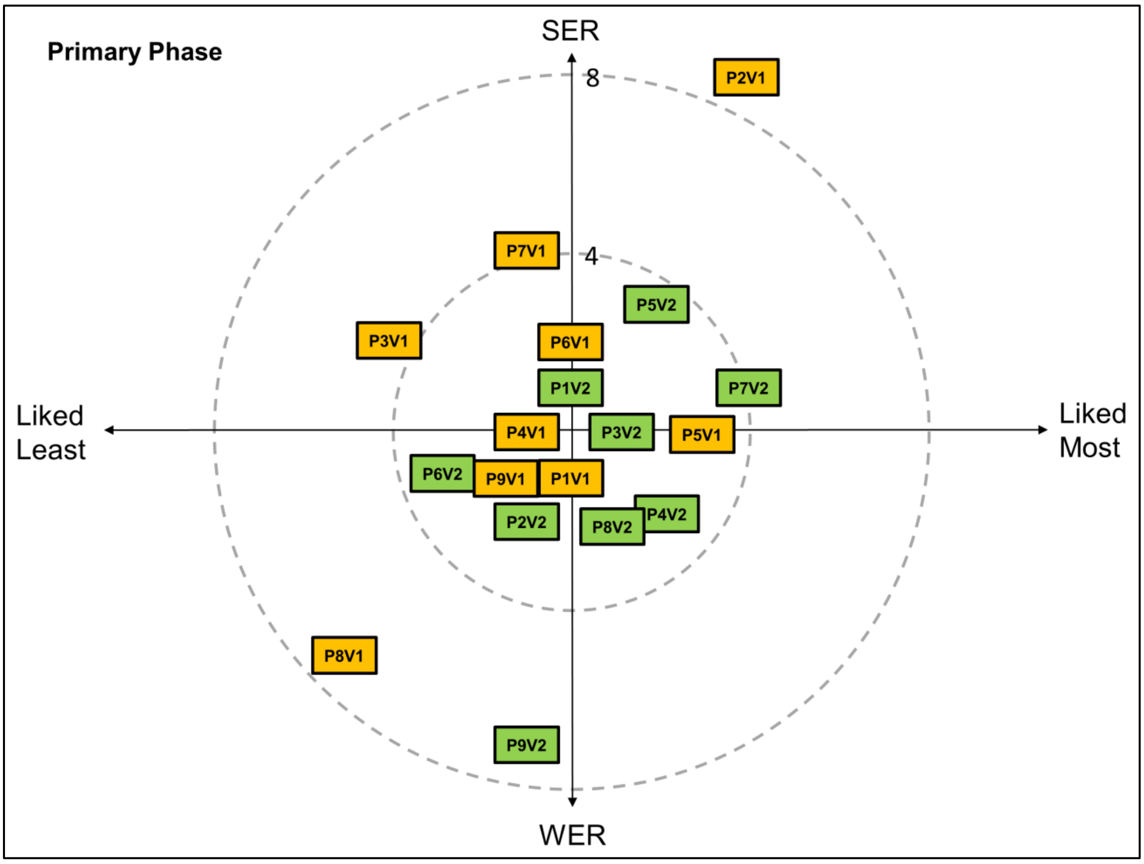


Fig. 4.14 - Primary Phase Part 2: Perception matrix of cumulative appraisals

The overall results of the primary phase presented in fig. 4.14 illustrate where the cancellation effect has occurred. In the case of concept P9v2a this has meant that despite eliciting the highest WER count and a significant number of liked-least selections, it appears almost neutral for preference due to a similar number of liked-most selections.

It is apparent from these observations that the perception matrix by itself can appear ambiguous due to the way that opposing values cancel each other out. The result can be to misrepresent strong disagreement as neutral or impassive agreement. The perception matrix should therefore be analysed alongside appropriate information detailing the magnitude of the responses.

Fig 4.15 also shows that there were very few instances of concepts with both high liked-most and WER counts. On the other hand, it is clear that the liked-most and highest SER concepts do coincide (i.e. concept p2v1a). Correspondingly, the liked-least concept (P8v1a) received considerably more WER than SER selections.

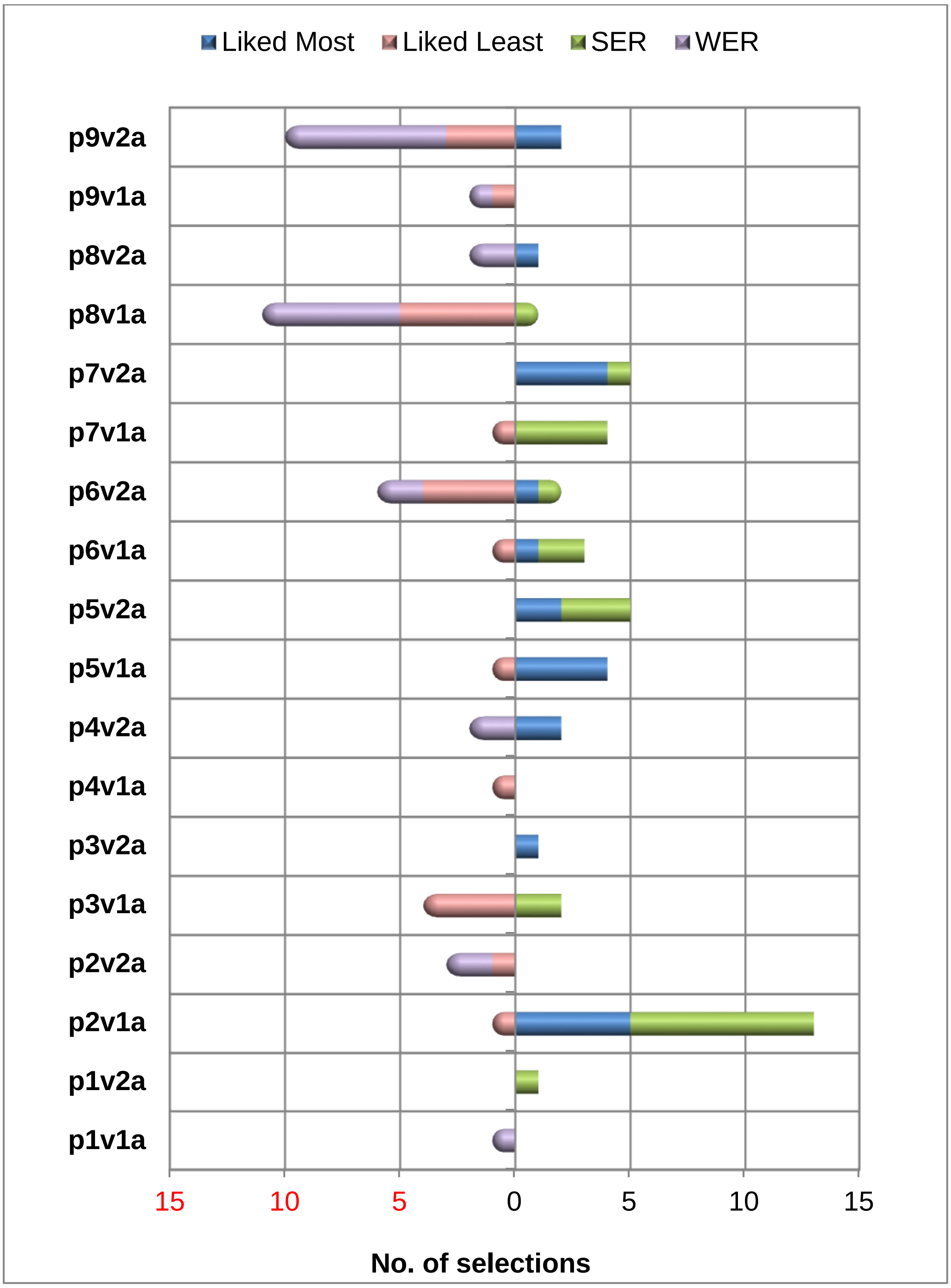


Fig. 4.15 - Primary Phase Part 2: Appraisals of vase concepts

Overall collective values were calculated by taking the sum of all the preference and emotional responses for all eighteen concepts used in the primary phase. Non-randomly created concepts scored -5 for preference and +9 for emotional response collectively. The randomly generated concepts scored +5 for preference and -9 for emotional response collectively. So although the randomly generated concepts were generally liked most, as a group the non-randomly generated concepts elicited stronger emotional responses (fig 4.16).

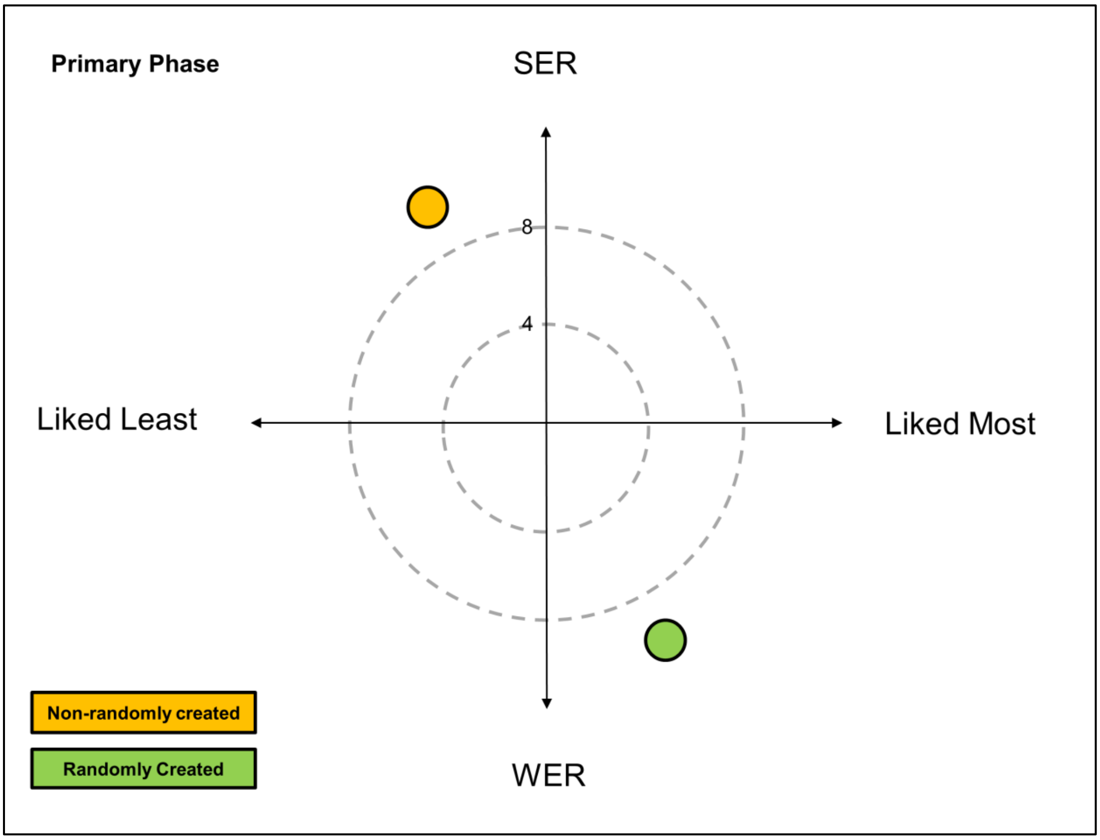


Fig 4.16 - Primary Phase Part 2: Collective values by concept creation method

4.4.4 Verification Phase - Part 1 (Design Activity) Results

The verification phase was essentially a repeat of the primary phase and the design of part one was identical. However, there were a number of differences including:

1) A different final year cohort of BU Industrial Design students partaking in the study;

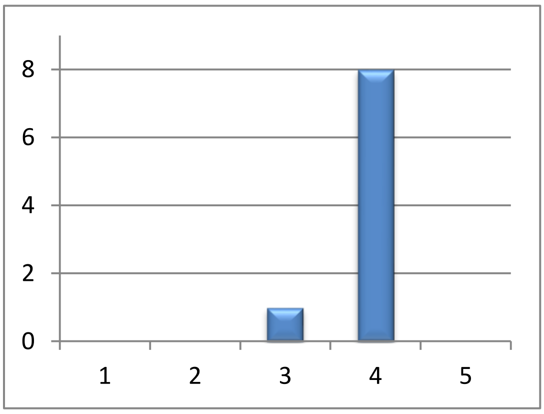
2) New concepts were created in the design part for appraisal;

3) A modified concept appraisal questionnaire format was adopted;

4) The addition of a third verification test (Part 3), which compared the most liked concepts overall from both the primary and verification phases.

All participants in group A2 completed the same questionnaire as those in the primary phase and were given the same instructions. In essence the results from the verification phase were very similar to those in the primary phase. A summary report is included here for consistency and comparison.

As in the primary phase, all nine participants indicated that their impression of interacting with both CAD tools had been positive, scoring 4 or above on a 5-point Likert scale (fig 4.17).



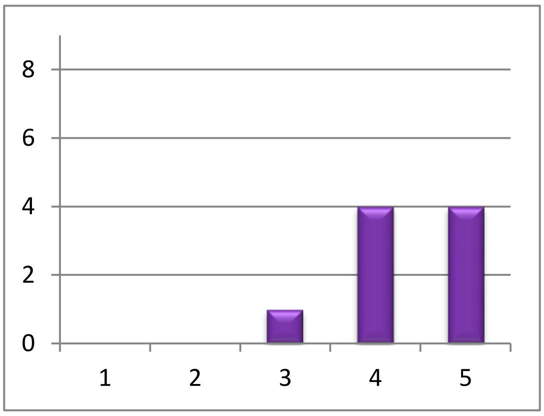
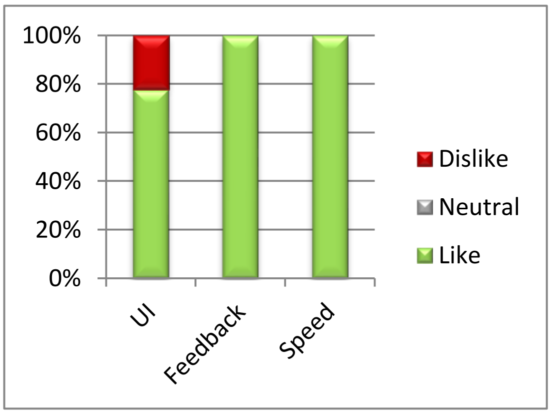


Fig. 4.17 – Verification Phase Q1. Overall impressions from the CAD tool interaction
(Left: Non-random CAD tool, Right: Random CAD tool)

All participants indicated that they liked the speed of both tools, but fewer of them liked the random CAD tool's control interface and feedback (fig 4.18). One participant commented that they felt the non-random CAD tool produced a good breadth of results despite the constrained parameters, while another wanted more controls and capabilities. A third commented that they had difficulty finding previously (manually) created shapes once they adjusted the modifiers' values.



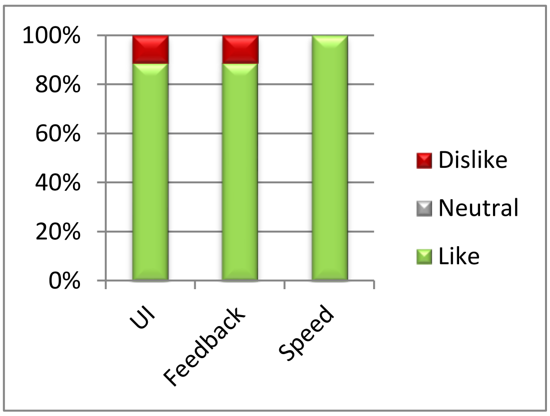


Fig 4.18 – Verification Phase Q3. Extent to which designers liked the concept they created
(Left: Non-random CAD tool, Right: Random CAD tool)

Eight of the nine participants indicated that they liked (point 4 on a 5-point Likert scale) the concepts they created using the non-random CAD tool. Every participant indicated that they liked the concepts they created using the random CAD tool (fig 4.19).

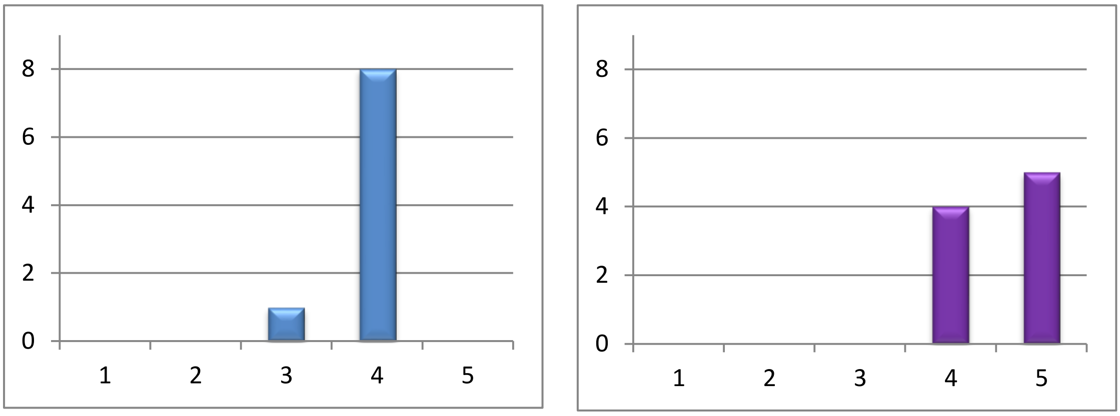


Fig. 4.19 - Verification Phase Q3. Extent to which designers liked the concept they created (Left: Non-random CAD tool, Right: Random CAD tool)

Only one participant considered their manually created concept to be original (point 4 or above on a 5-point Likert scale), while three indicated that they believed their concepts looked unoriginal (fig 4.20). Five participants considered their randomly created concepts to be original.

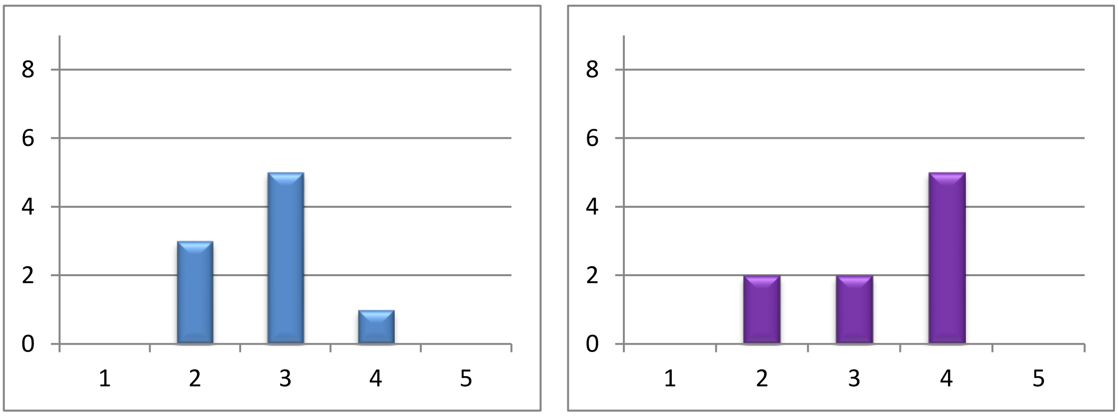


Fig. 4.20 - Verification Phase Q4. Extent to which designers considered their concept original (Left: Non-random CAD tool, Right: Random CAD tool)

Four participants indicated they thought their manually concepts demonstrated little surprise while five indicated significant surprise (fig 4.21). Seven considered their randomly created concepts to be significantly surprising (rated 3 or above on a 4-point scale where 1= no surprise, 2 = little surprise, 3 = significant surprise and 4 = highly surprising).

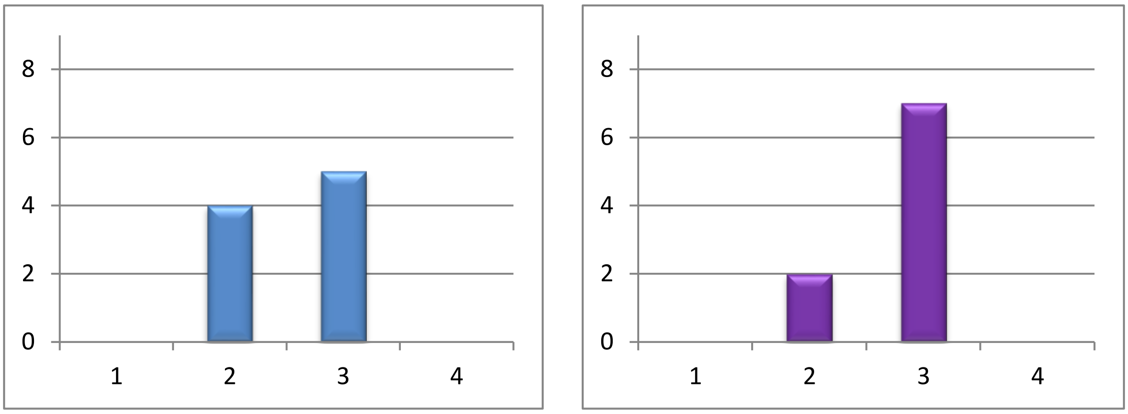


Fig. 4.21 - Verification Phase Q5. Extent to which designers considered their concept to be surprising (Left: Non-random CAD tool, Right: Random CAD tool)

The designers' impressions regarding the emotional affect of their concepts were positive with eight participants considering their manually created concept to elicit a significant emotional response or higher (rated 3 or above on a 4-point scale where 1 = no emotion, 2 = little emotion, 3 = significant emotion and 4 = high emotion). The results for the randomly created concepts were exactly the same (fig 4.22).

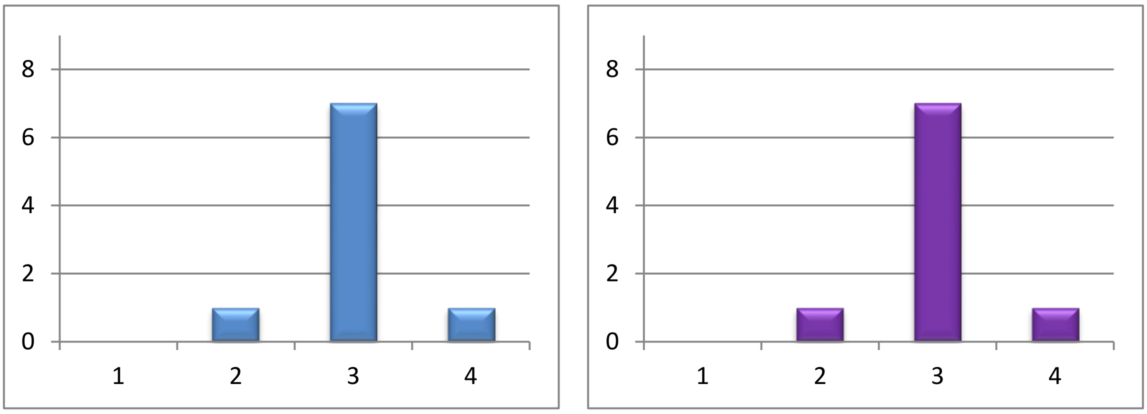


Fig. 4.22 - Verification Phase Q6. Extent to which designers considered their concept elicited an emotional response. (Left: Non-random CAD tool, Right: Random CAD tool)

4.4.5 Verification Phase – Part 2 (Appraisal Activity) Results

Group B2's responses to the concepts created by group A2 were collected and collated for analysis in the same way as before. The randomly and manually created concepts were grouped on separate pages of the questionnaire and the appraiser participants were asked to select concepts from *both* groups, although they were not made aware of how the groups were comprised. This meant that the overall count density was effectively doubled for the same number of participants, fig.4.23.

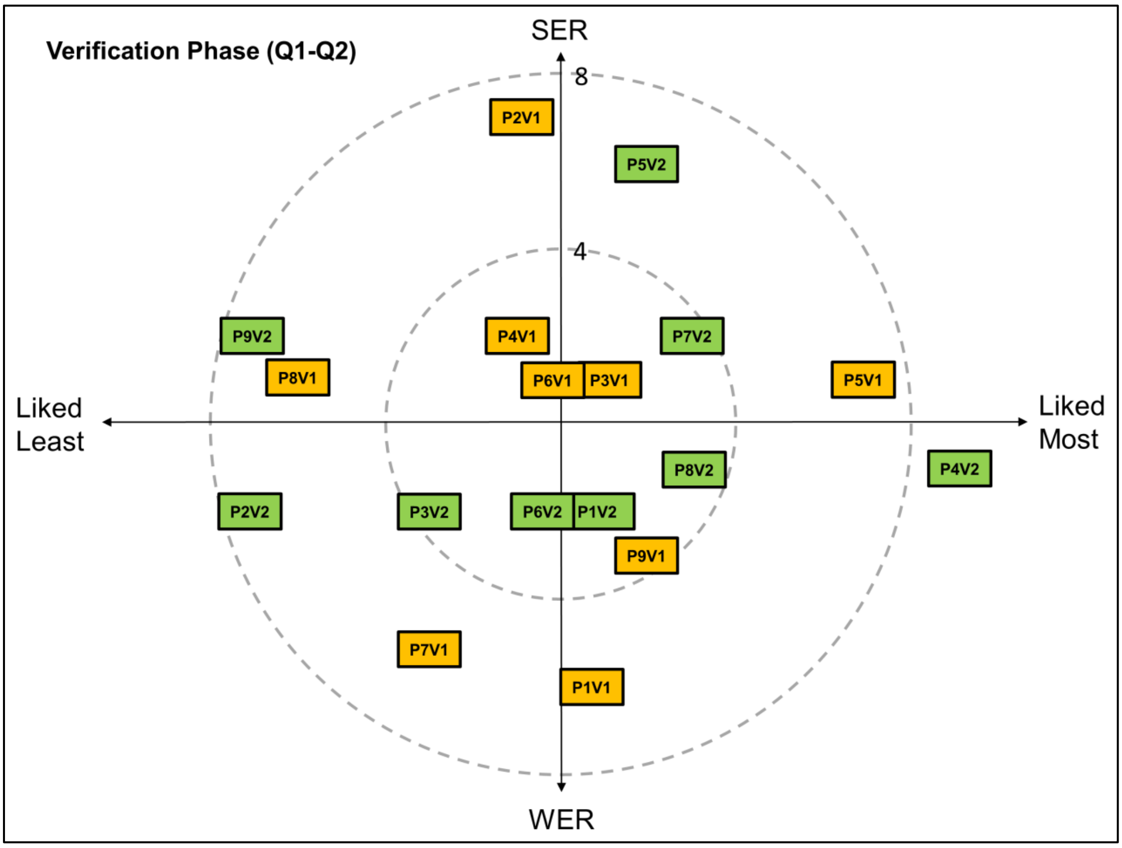


Fig. 4.23 - Verification Phase Part 2: Perception matrix of cumulative appraisals

The results of the verification phase indicated that there were more concepts registering conflicting selections (i.e. Like most *and* Like least, or WER *and* SER) than in the primary phase. The liked-most concept (P4v2b) was found to have registered both SER and WER selections. Fig 4.24 indicates that there were 5 WER and 4 SER selections for that concept, resulting in a seemingly almost neutral outcome. Concept P2v1b, which received the highest SER count overall, received almost as many liked-most selections as liked-least. It is noteworthy that this concept was the most similar of all the verification phase concepts to the SER concept from the primary phase (i.e. P2v1a).

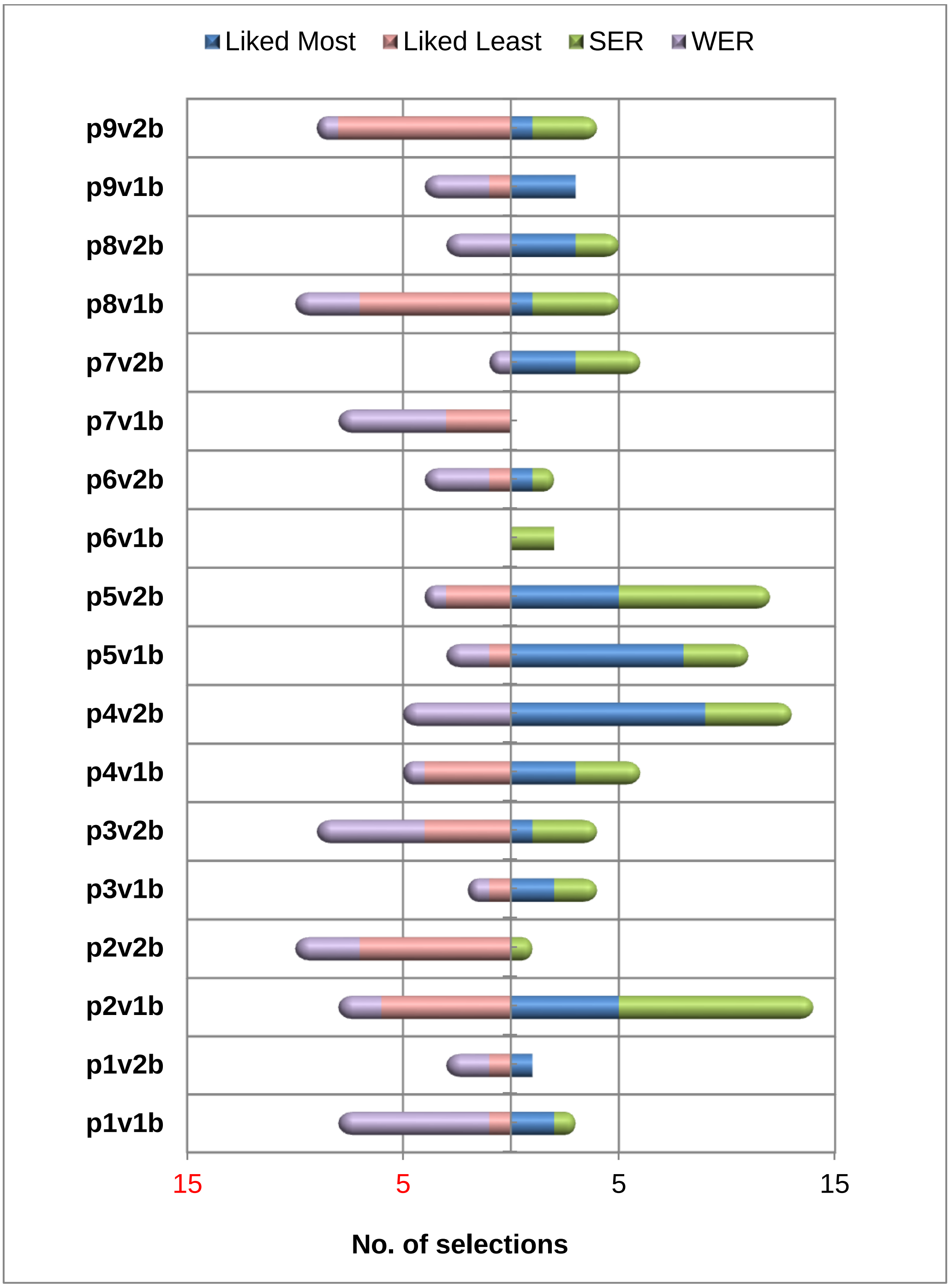


Fig. 4.24 – Verification Phase Part 2: Appraisals of vase concepts

Concepts P8v1b and P9v2b were the least liked concepts. Concept P9v2b received a number of SER selections and one WER selection. P8v1b received almost equal numbers of SER and WER selections. P7v1b was the most consistently WER concept with 5 WER and no SER selections.

The change made to the questionnaire format ahead of the verification phase meant that the concepts were split into randomly and non-randomly generated categories. As a result, it was not possible to calculate collective responses from this data. However, this issue had been foreseen, so participants were additionally asked to identify the concept(s) that that they liked most/least and that elicited the WER/SER overall.

The overall ratings of the concepts in the verification phase (fig 4.25) indicate that concept P4v2b was still the most liked concept. All its relative values remained similar with the exception of the WER selections, which were slightly fewer than before. In contrast, the equivalent values for concept P2v1b were all halved or less. At the other extreme, the least liked concepts from the initial appraisals of the verification study concepts were P8v1b and P9v2b. These were again the least liked overall, albeit with a slightly lower count. Each concept received selections both for overall SER and WER.

Overall collective values were calculated by taking the sum of all the preference and emotional responses from the overall ratings of the eighteen concepts used in the verification phase. Non-randomly created concepts scored -1 for preference and -3 for emotional response on. The randomly generated concepts scored +1 for preference and +3 for emotional response (fig 4.26).

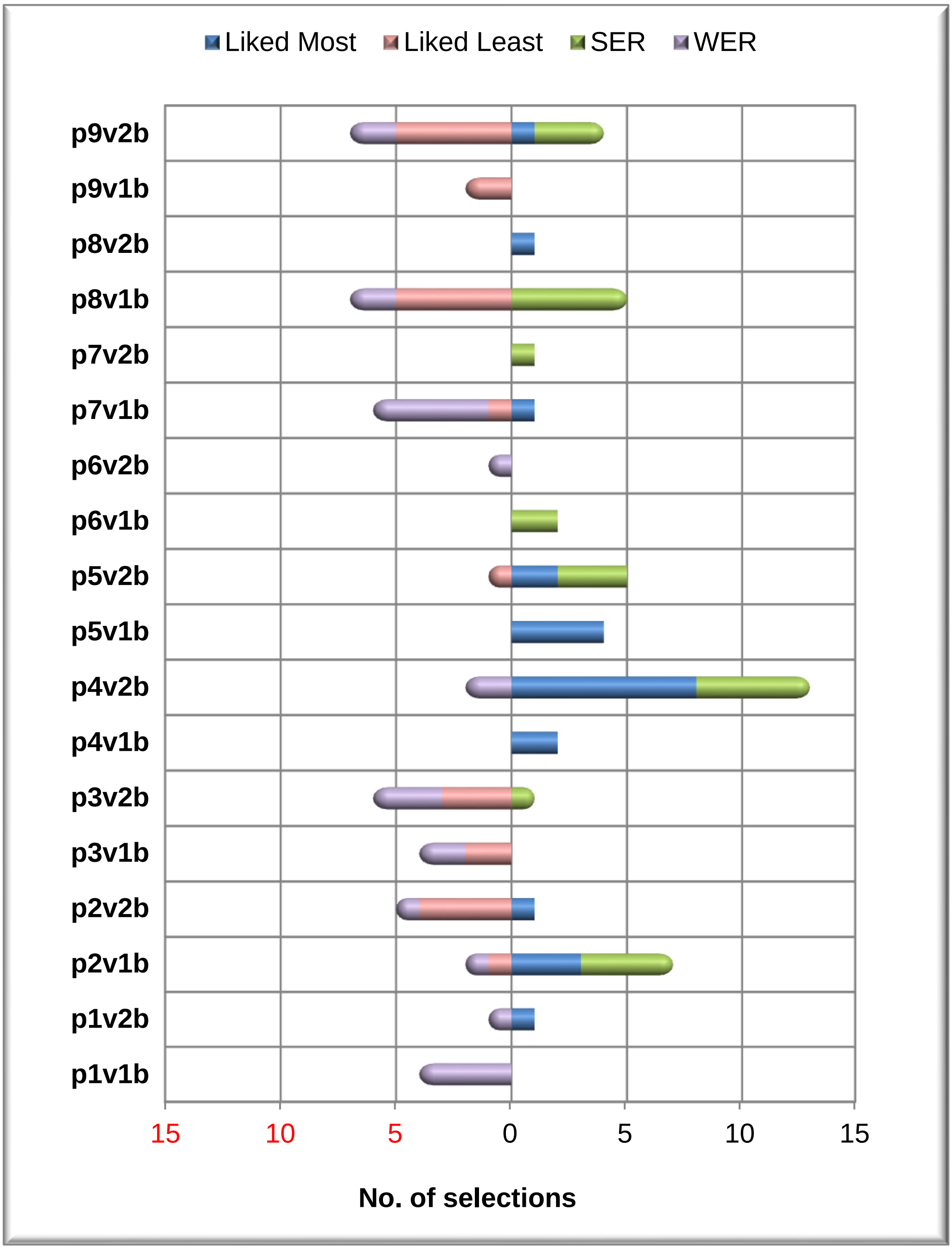


Fig 4.25 – Verification Phase Part 2: Overall appraisals of vase concepts

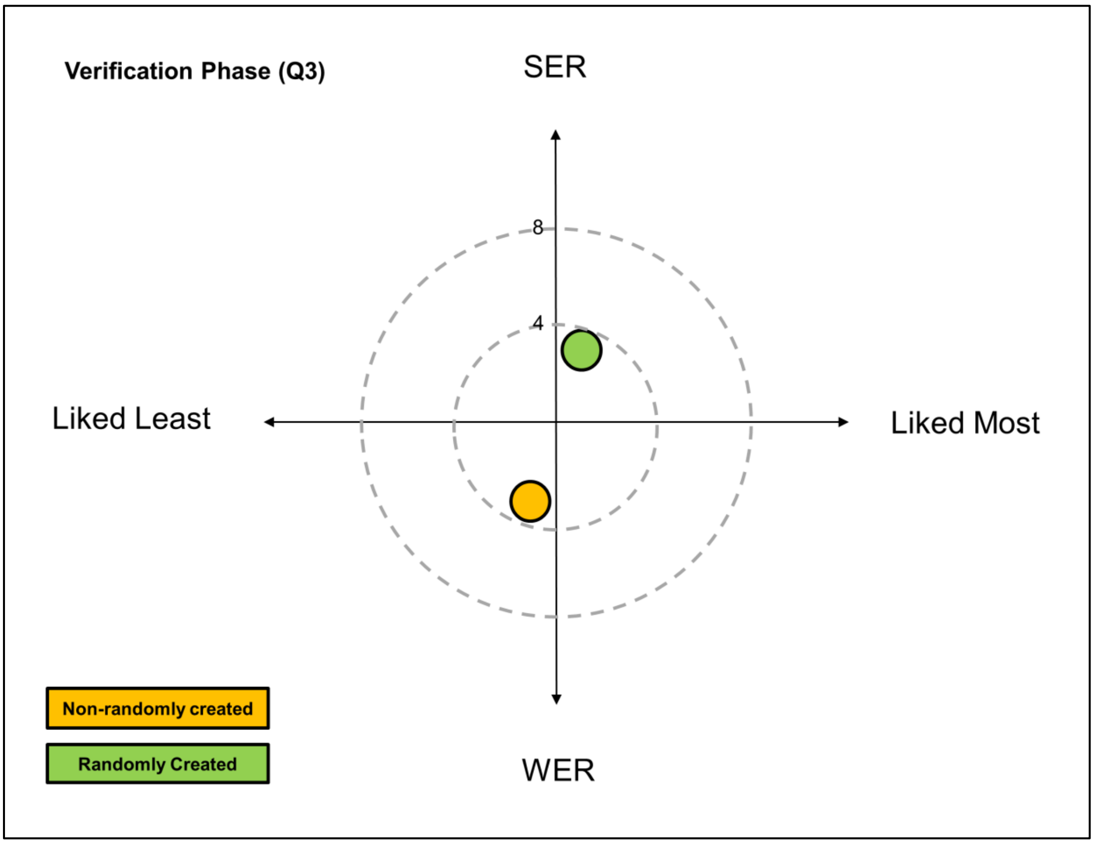


Fig 4.26 – Verification Phase Part 2: Collective values by concept creation method

4.4.6 Comparison Activity Results

The final part of the verification phase was a questionnaire-based comparison of the two most liked concepts from part 2 of the primary and verification phases (fig. 4.27). Each concept had been created by different means (i.e. one random, one non-random). Responses were provided by a separate group of participants. The group consisted of seventeen, mixed gender, BA (Hons) Industrial Design students. These participants were given a different questionnaire to those in part 2 (Appendix K). Neither concept had been compared to the other until this point.

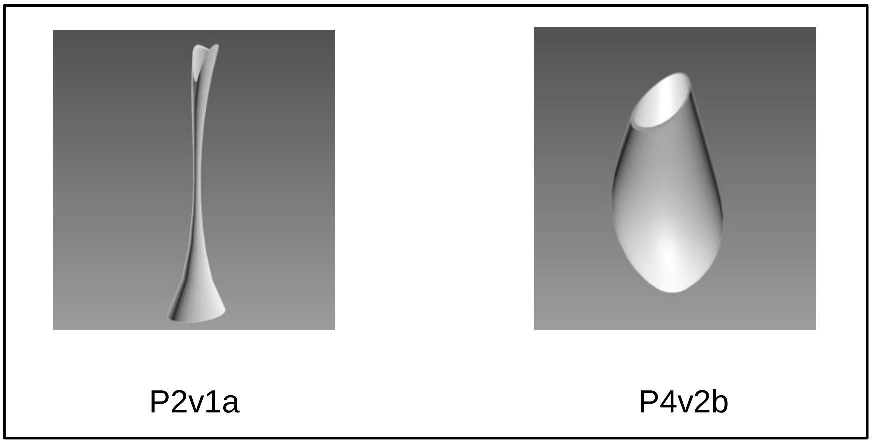


Fig. 4.27 - Verification Phase Part 3: Comparison concepts

The aim of the comparison activity was to investigate some of the results from the primary and verification phases in more detail. The objective being to gain a more detailed understanding of the responses elicited by selected concepts from each phase. First, participants were asked to indicate which of the two concepts they liked most and secondly, which concept they considered elicited the strongest emotional response (fig. 4.28)

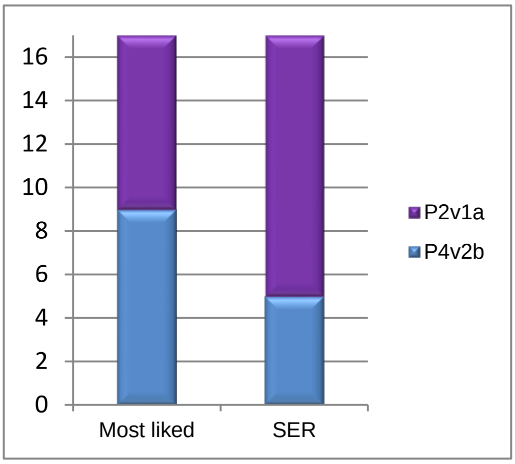


Fig. 4.28 - Verification Phase Part 3: Concept comparison

Both concepts were liked to a very similar extent, with the random concept just coming out on top (P2v1a: 47%, P4v2b: 53%). However, the SER elicited by the manually created concept was much higher (P2v1a: 71%, P4v2b: 29%).

Participants were asked to indicate whether they experienced certain emotional responses to each of the concepts using a semantic differential on a 5-point Likert scale. See Appendix O for a full numerical breakdown of these results.

The first pair of emotional responses used for comparison was Pleasant and Unpleasant Surprise (fig 4.29). The Pleasant Surprise response to the manually created concept (P2v1a) was far greater than in response to the randomly created concept (P4v2b).

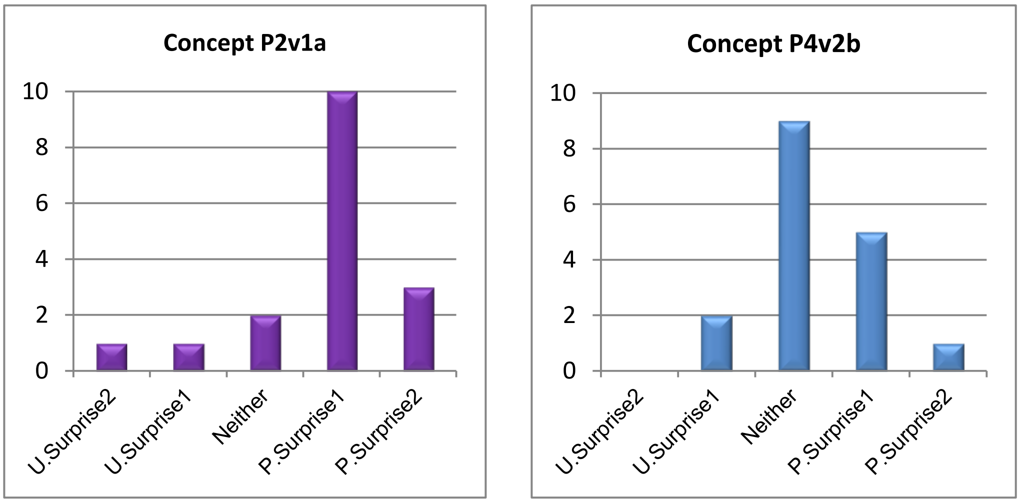


Fig 4.29 - Verification Phase Part 3, Q1: Unpleasant/Pleasant surprise

The second pair of emotions used for comparison was Desire and Disgust (fig. 4.30). The Desire response to the manually created concept was only slightly higher than that of the randomly created concept.

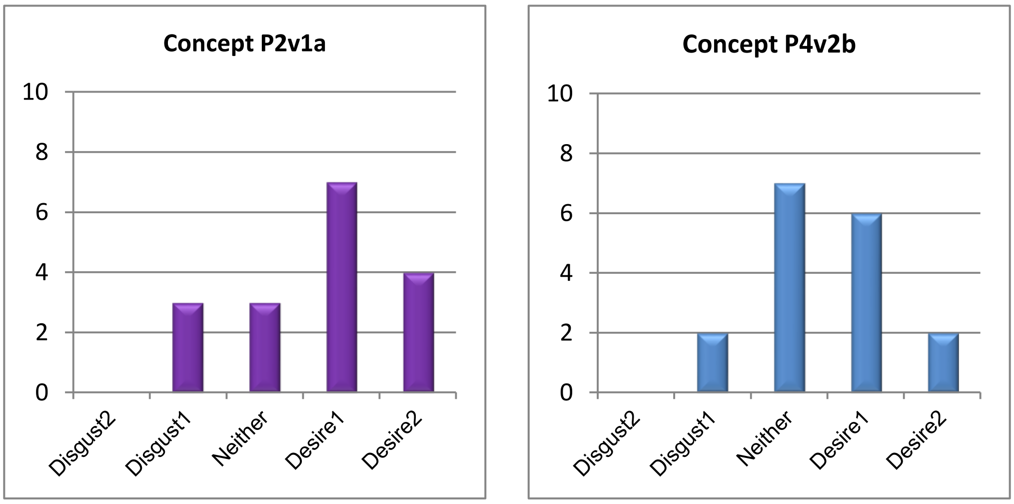


Fig 4.30 - Verification Phase Part 3, Q2: Disgust and Desire

The third and final pair of emotions used for comparison was Stimulation and Boredom (fig 4.31). The Stimulation response to the manually created concept was highest, that being the only concept to register a ‘very stimulating’ response.

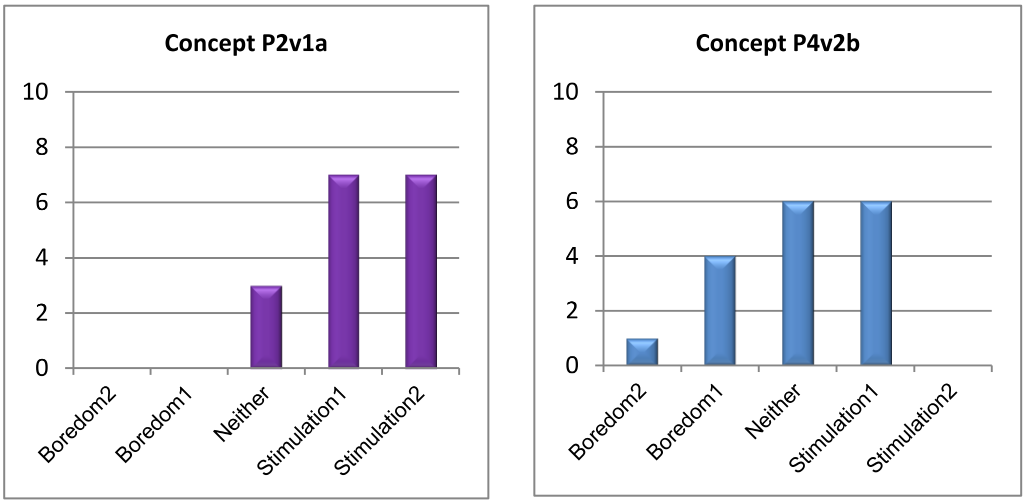


Fig 4.31 - Verification Phase Part 3, Q3: Boredom and Stimulation

4.4.7 Discussion

The main study sought to answer the primary research questions (Chapter 1.5). The following sub-section describes and evaluates various methods that were employed to interrogate the results of that study.

4.3.7.1 Design Activity Evaluation

The design activity served to indicate whether the CAD tools were perceived as useful and fit for purpose by the intended user group and address the secondary research question. The results were very similar for both phases of the study. The CAD tools with which the designers were provided were merely prototypes offering limited functionality and so the comments that eluded to that effect were somewhat anticipated. Never-the-less, the designers did not indicate that this limitation left a negative impression. Instead, they received the CAD tools with intrigue and enthusiasm, enjoying interacting with and exploring both random and non-random versions. In particular, they liked the way that the random CAD tool could generate unexpected results from which they could take inspiration for further design concepts, rating its output as being highly original.

It was noted that one participant had encountered difficulty in recreating a previously rejected concept. The lack of any undo function was partially responsible for this and was due to the way each modification to the CAD model resulted in previous values being overwritten. Another contributing factor was the absence of any numeric values on the user interface. The CAD tools used were highly simplified and focussed on the creation of a single product type. Simplicity and intuitiveness were considered a priority for the purposes of the study. The addition of further complexity would potentially have increased the time required to become familiar with the tool's function and subsequently reduced operator satisfaction.

4.3.7.2 Appraisal Activity Evaluation

The Appraisal activity was intended to address the remaining research questions. The analysis of the data was undertaken in a variety of ways in an attempt to use the most suitable approach in each case. These different approaches included:

i. Concept Ranking
ii. Visual appraisal of the results from each phase
iii. Parametric analysis of the results from each phase

Concept Ranking

Concepts in the primary and verification phases were ranked. The rankings were determined for each concept as follows:

a) The sum of the liked-least count was subtracted from the sum of the liked-most count to achieve a cumulative preference value for each concept.
b) The sum of the WER count was subtracted from the sum of the SER count to achieve a cumulative emotional response value for each concept.
c) The cumulative values for like and emotional response were ranked low to high according to their values in a) and b).

Ranking was undertaken in order to establish whether there was a relationship between the strength of elicited emotional response and the likeability of a design concept and to compare the strength of elicited emotional responses between randomly and non-randomly created concepts. Initial ranking was based on the ratios of liked most against least and SER against WER ratings (Appendix P).

The initial rankings from the primary phase indicated a correlation between the most liked concept and the concept eliciting the strongest emotional response (p2v1a). The opposite was evident at the other end of the scale, with correlation between the concept being least liked and eliciting the weakest emotional response. However, due to the polarised nature of the appraisal process (i.e. select the most/least, strongest/weakest…) the intermediate positions were not found to be as reliably indicative. This was because the intermediate rankings were obtained indirectly as a by-product of those concepts having received only a moderate number of selections, rather than having been given a specific neutral rating (e.g. as would have been the case with a Likert scale). In other words, a minority of appraisers regarded intermediate concepts as the strongest/weakest, even when the overwhelming majority did not. Significant bunching of mid-ranking concepts was apparent, no doubt as a result of this cancellation effect.

Similar characteristics were observed in the verification phase. However, the most liked concept in the Verification phase (P4v2b) received a similar number of SER and WER ratings, meaning its cumulative emotion value was actually negative (i.e. SER 4: WER 5). Never-the-less, on the strength of its like-most/least ratio (i.e. liked most 9: liked least 0), the product of its cumulative values placed it at the very top of the rankings. Conversely, the least liked concept (P9v2b) received a fairly low ratio of SER/WER ratings (i.e. SER 3: WER 1) that produced a slightly positive cumulative emotion ranking. The product of its cumulative values moved this concept several steps up from the bottom of the table.

Visual comparison of the concepts produced

A visual appraisal was made of the concepts produced during the main study. The objective of this exercise was to identify particular characteristics that might differentiate or be shared between the top and bottom ranked concepts. It was envisaged that this would help deduce what factors contributed to the relative position of the concepts produced in each phase. (Tables 4.2 and 4.3)

Table 4.2. Visual Comparison Summary: Primary Phase

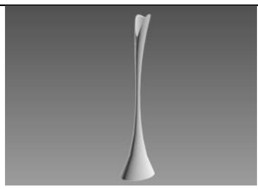
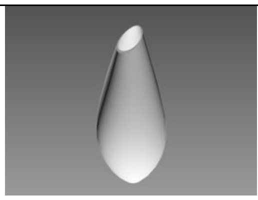
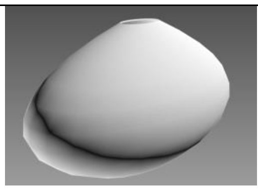
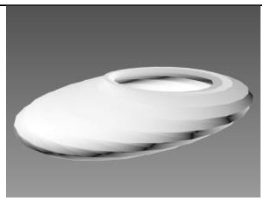
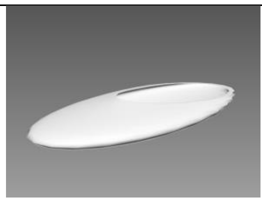
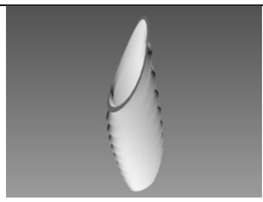
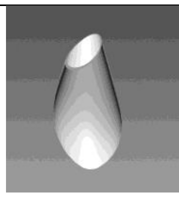
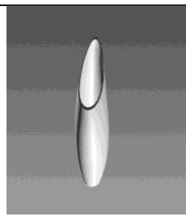
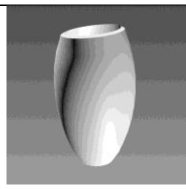
P2v1a was found to be both the most liked *manually* created concept and the most liked concept overall. It was also the concept most frequently selected as eliciting the strongest emotional response (SER) overall.	 P2v1a
P7v2a was the most liked *randomly* created concept, but only received a moderate number of SER selections. It was also considered to be visually similar to concept P4v2b in the Verification phase.	 P7v2a
P8v1a was *manually* created and was the least liked concept overall. It was also close to being the concept most frequently selected as eliciting the weakest emotional response (WER) overall.	 P8v1a
P6v2a was one of the least vase-like concepts and was the least liked *randomly* created concept. This concept was also considered to be highly atypical.	 P6v2a
P9v2a was *randomly* created and was the concept most frequently selected as eliciting the weakest emotional response (WER) overall. It was the least vase-like concept created overall. This concept was also considered to be highly atypical.	 P9v2a
P5v2a was the *randomly* created concept most frequently selected as eliciting the SER, but only received a moderate number of most liked selections.	 P5v2a

Table 4.3 - Visual Comparison Summary: Verification Phase

P5v1b was the most liked *manually* created concept.	 P5v1b
P4v2b was the most liked *randomly* created concept and the most liked concept overall. It was also considered to be visually similar to concept P7v2a in the Primary phase.	 P4v2b
P2v1b was the least liked *manually* created concept but it received almost as many most liked selections. It was also the overall concept most frequently selected as eliciting the strongest emotional response (SER).	 P2v1b
P5v2b was the *randomly* created concept most frequently selected as eliciting the strongest emotional response (SER).	 P5v2b
P1v1b was *manually* created and was the concept most frequently selected as eliciting the weakest emotional response (WER) overall.	 P1v1b
Concept P8v1b was a *manually* created concept that was one of the least liked concepts overall, but also one of the most frequently selected concepts for eliciting the strongest emotional response (SER). It was also considered visually similar to concept P3v1a in the Primary phase of the Main study.	 P8v1b

The visual appraisal was undertaken to analyse the results of both phases of the Main study in terms of the following:

- Similarity of concepts

Where concepts in one or both phases of the Main study were regarded as visually similar, their rankings were compared to see if the participants' perceptions of those concepts were consistent. The findings of this analysis were that similar concepts were found to have been ranked in similar positions. For example, P7v2a (Primary phase) and P4v2b (Verification phase) were considered similar and were both the most liked randomly created concepts. Furthermore, P3v1a (Primary phase) and P8v1b (Verification phase) were considered similar (Appendix L). Both of these concepts were found to occupy the same quadrant of their respective perception matrices (see figs 4.14 and 4.23)

- Typicality of concepts

Where concepts in one or both phases of the Main study were regarded as highly typical or atypical, their rankings were reviewed to see what, if any, relations may exist between typicality, preference and/or emotional response. The findings of this analysis were that highly atypical concepts were generally disliked, e.g. P6v2a and P9v2a (Primary phase).

- Aesthetic features of concepts

Even though a detailed parametric analysis would subsequently be undertaken on each concept produced during the Main study, a visual appraisal of each concept's aesthetic features was also carried out in an effort to determine whether a concept's ranking could be linked to particular types of feature or proportion. The findings of this analysis were that a low height to width ratio was generally more disliked e.g. P6v2a, P8v1a and P9v2a (Primary phase). Furthermore, concepts exhibiting the results of a high twist angle were generally found to be more disliked, although the effect did appear to contribute to elevated SER rankings.

Parametric analysis of the results from each phase

Parametric analysis and comparison was undertaken in an attempt to identify whether particular geometric features might be responsible for eliciting strong emotional responses. A detailed breakdown of the parametric characteristics can be found in Appendix Q. Further to this, the main variables used to construct each concept were recorded and compiled in tables for comparison in Appendix R. The overall variable tables were visually appraised for similarities, while the top and bottom ranked concepts (for like most/least and SER/WER) were afforded closest attention. The values of individual construction parameters were averaged to see if there were commonalities that occurred between the top or bottom performing concepts when compared to the overall results from both studies.

The parametric comparisons indicated trends linking the geometric construction of the concepts with like/dislike and emotional response. The following attributes were found to differ significantly, although the underlying reasons were not pursued further as part of this research:

a) Proportion: For the given product context (vase), an upright, vertical orientation was generally preferred to a wide or horizontal one. Furthermore, the top SER concepts had an average proportion ratio of 33.1 (min: 9.0, max: 47.8) compared to the overall proportion ratio of 195.8 (min: 9.0, max: 3401.9).

b) Stretch and Squeeze: The magnitude of the parameters for these modifiers were generally quite small compared to others. However, a small adjustment of the stretch value can result in a vastly different shape (fig 4.32). The squeeze modifier had the effect of making the CAD geometry proportionally thinner regardless of the value used. Positive and negative values changed the convex or concave curvature of the effect (fig 4.33).

Using a positive variable for the stretch modifier tended to augment the vertical, hour-glass proportions while a negative radial squeeze value contributed to the narrowing of the vertical proportion, resulting in a thinner form. In general, those concepts in both the main and verification studies with a higher stretch value and a more negative squeeze value elicited a stronger emotional response.

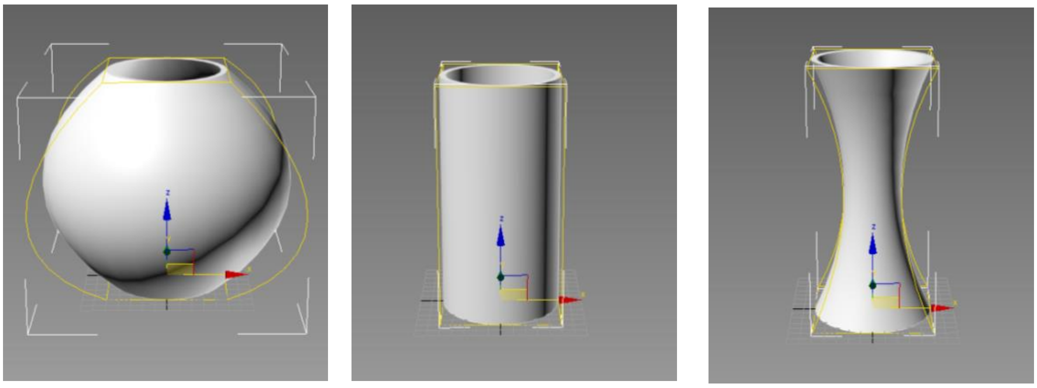


Fig. 4.32 - Effect of stretch modifier application
(Left: -0.4, Middle: 0.0, Right: +0.4)

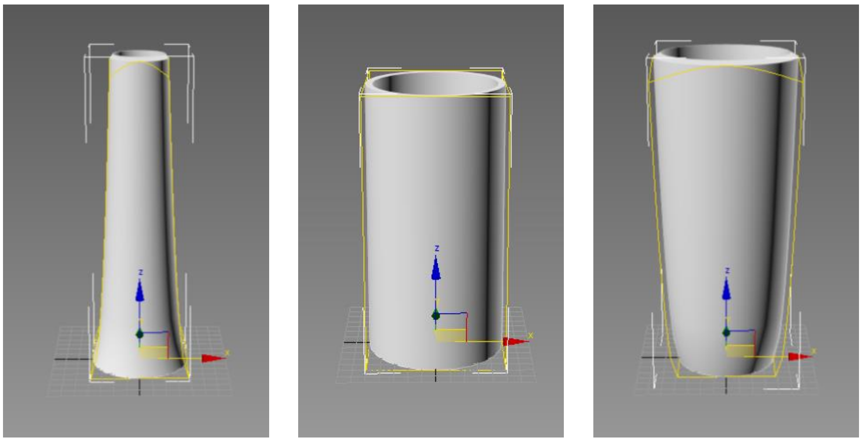


Fig. 4.33 - Effect of squeeze modifier application
(Left: -0.3, Middle: 0.0, Right: +0.3)

c) Twist angle: The average twist angle applied to the most liked concepts was 13° (min: 0, max: 51.0). Two of the top SER concepts and one of the lowest WER concepts featured no twist angle at all. The least liked concepts had an average twist angle forty times greater than that of the most liked concepts. In general, this would appear to suggest that the appraisers found this effect undesirable, although examples of commercially available vases exhibiting similar features were found to be readily available (Appendix F) indicating that this feature was appropriate for the product genre, but considered undesirable by the study participants.

d) Bend angle: The mean bend value for the top SER concepts was 26° (min: 23.1°, max: 30°). This figure was almost twice as high as that of the lowest WER concepts at 15° (min: 0°, max: 30°). The mean bend angle for the most liked concepts was 18° (min: 8°, max: 30°), compared to just 7° (min: 0°, max: 24°). for the least liked concepts. Overall, this suggests that the bend modifier produced an effect that the appraisers found desirable for the given product context.

4.8.7.3 Comparison Activity Evaluation

The comparison activity was intended to explore the following:

- What differences can be observed between the likability of randomly and non-randomly generated concepts?
- What relationships can be observed between the strength of elicited emotional response and the likeability of a design concept?
- Does the strength of elicited emotional responses differ between randomly and non-randomly created concepts?

The two concepts used in the comparison activity were created in different phases of the main study. As a result, they had not been scrutinised together at any other stage previously. It was therefore unclear whether the most liked manually created concept overall (P2v1a) would be appraised differently alongside the most liked randomly generated one (P4v2b).

The comparison activity found that in terms of likeability, the randomly generated concept was marginally more popular (9:8 in favour of P4v2b). In this part of the study, the opportunity was taken to better understand the emotional responses elicited by each vase concept. In this respect the manually created concept (P2v1a) was found to out-perform the randomly created one in all three areas surveyed. It was considered at least twice as *surprising* and *stimulating* as the randomly created concept, although the randomly created concept was considered almost as *desirable* as the manually created one and was marginally the most *liked* of the two. These results would indicate one or more of the following:

- Likeability of the non-randomly created concept was not significantly affected by a positive surprise or stimulating emotional response.
- The positive surprise elicited by the non-randomly created concept was still relatively weak and its effect quickly diminished.
- Other factors (e.g. perceived functional attributes) contributed to the randomly generated concept being slightly more likeable than the non-randomly created concept.

Overall, the most surprising concept was found to be the non-randomly created one. The predominantly neutral (unsurprised) response to the randomly created concept suggests that it demonstrated a significant level of prototypicality. Both concepts were considered to be desirable to a similar extent however, supporting the idea that typicality in itself is not an undesirable design characteristic. It is significant that the non-randomly created concept was considered to be considerably more stimulating. Such a high level of stimulation could in itself have contributed to the level of surprise experienced by the participants. It is conceivable that if the experiments were repeated that the concepts would differ due to the particular skill level of the designer participants and the level of unpredictability effecting the random concept creation process. These aspects of the study are non-repeatable, but it is likely that the responses to other concepts would be consistent with these results, that indirectly support the findings in the literature review linking play and creativity and surprise and emotion. Furthermore, they show that the application of randomness can be used to elicit emotional responses in product design.

4.4.8 Observations and Limitations

A number of observations were made during the course of the main study that could be regarded as having implications on the research outcomes. Furthermore, there are acknowledged limitations associated with variables in the research methods and analysis. These limitations could be seen to have affected the extent to which the research questions were addressed and are therefore discussed here as part of the evaluation of the research methodology.

i. Concept Variety and Parametric Constraints

The range of possible concepts that could be created by each of the CAD tools was determined by the starting geometry (cylinder) and the nature and number of modifiers applied using the scripts in 3DSMax. Furthermore, the parametric constraints used in both tools had a major influence on the way the vases' constructions were influenced. As a result, the extent of possibilities the CAD tools were capable of was by no means exhaustive, nor was it intended to be so. Instead, the CAD tools employed during the study were designed to be capable of creating sufficient flexibility such that they would provide a greater breadth of possibilities than could be exhaustively explored in the time available. At the same time, the UI's were designed to be uncluttered, intuitive and easy to use. In these respects the tools were largely successful, with only a minority of designer participants indicating that they would have liked additional functionality to manipulate their concepts further.

Each designer participant appraised a total of fifty pseudo randomly generated concepts. The constraints on the variables used to create these concepts were such that this number was highly unlikely to represent the full extent of possible permutations. Each designer participant would have seen some concepts that appeared similar to each other, whilst many others looked quite distinct. This was also observed to be the case *between* designer participants (unbeknown to the participants themselves) with the sporadic appearance of decidedly similar concepts throughout the course of both studies.

ii. Participation Variables

All participants were final year BA (Hons) Industrial Design students at Bournemouth University. They were deemed appropriate due to their particular area of study and the fact that they were close to completing their undergraduate studies. The samples were considered representative given the aims, objectives of this phase of the research.

All participants were solely reliant on their own personal experience with no access to source material for inspiration. This meant that any subjective analysis of their concepts (e.g. like, emotional response) was based on those individuals' interpretation of the design brief in that moment. However, many of the concepts selected (both random and non-random) bore resemblances to commercially available products (Appendix F). This suggests that the designers were suitably familiar with the product context and the CAD tools were generally fit for purpose in their ability to generate appropriate design concepts. Furthermore, while the designers were at liberty to ask questions about the brief, very few actually did, preferring instead to engage with the creative activity itself rather than procrastinate over the *client's* particular requirements. Similarly, none of the appraiser participants sought additional clarification of what was meant by a *strong* or *weak* emotional response beyond the briefing they were provided with prior to commencing the appraisal activity. This would suggest that the instructions were clear and understood.

Each individual design participant session lasted just thirty minutes. This meant that the actual creative activities were limited to approximately ten minutes per CAD tool. As a result, the designers had a very short period of time within which to digest the requirements of the brief and complete their best attempt at conceptualising a product of that type. While the time and instructions were the same for all participants, the outcomes cannot be directly compared to what might have been created under the same circumstances but by designers with no 'CAD tool'. Such an experiment would have been affected by the level of CAD proficiency and falls outside of the boundary of this PhD research project.

Finally, the design capabilities of each designer participant would have varied despite them all being final year Industrial Design students. This variation would have affected the designers' abilities to make informed decisions regarding their concepts during the creation and selection process. This inconsistency was anticipated and is largely inevitable in a study like this. However, it was expected that any significant impact would have been minimised by the incorporation of the verification and comparison activities.

iii. Effect of CAD tool operation and interaction

The contrast in the way users were required to interact with each of the tools seemed to affect their perceptions of the tools' capabilities. Both tools were capable of creating similar concepts, and yet the responses given by the participants indicated that they perceived the random tool to be more surprising. Circumstantial indications would suggest that this was because the random algorithms would occasionally produce combinations of values that the designers had not explored with the non-random CAD tool. The non-random CAD tool on the other hand, was incremental and could only modify one parameter at a time. This meant that the designers could, with a little practice, predict the effect of making adjustments and preconceive the outcome. It is possible (as a result of the limited time available) that the designers may have focussed their attention on producing something that looked credibly vase-like, rather than explore the full extent of the non-random CAD tool's capabilities.

iv. Presentation Media Variables

The designers created and viewed their concepts using a high definition PC monitor. As a result, the on-screen images were brightly and clearly displayed. The designers also had the ability to pan, zoom and rotate their view of their concepts. The final concepts were consolidated, randomly arranged and then printed on A3 paper before being distributed amongst the appraisers. All concepts were presented equally and appraisers could see all the concepts at once. However the images were printed and static. While it is possible that the effect of the onscreen images might have been different to that of the printed ones, all results used for comparison were taken across like-for-like media.

v. Concept Generation and Appraisal

It was observed that some concepts (those with randomised variables close to the mean value) would tend to look quite similar. Conversely, concepts with randomised variables closer to the parametric constraint boundaries would tend to look more unusual while occurring less frequently. The result of this meant that the mix of concepts created by each participant during the studies was entirely unpredictable. However, although the random CAD tool arbitrarily generated vase concepts based on pseudo-random parametric constraints, the designers were asked to select their preferred concept each time a new one was created. This meant that the final chosen random concept was subjectively selected.

It was observed that certain similar concepts would be generated from time to time that were quite distinctive. Due to the way that each concept was appraised against another, some designers chose to keep them while others chose to discard them, depending on the subjective preference of the designer and the relative likeability of the concept against which it was being appraised. The occurrences of these concepts were not apparent to anyone other than the researcher as the study progressed, as they appeared sporadically and across a range of participants. Neither were they formally recorded as it was only as the study proceeded that the occurrences were identified at all. However one notable example was the most liked/SER non-random concept from the Primary phase (p2v1a). Creation of similar concepts was observed by the researcher during the random concept creation activity, but they were not retained by the designers in those instances. This would indicate that the one-on-one comparison technique employed during the study, while expedient in reducing the number of concepts carried forward for appraisal, might not be the most effective method for concept selection since potentially valuable concepts may have been lost by gambling that a more appealing concept could be next.

Some of the designer participants' described (orally and unprompted) aspects of their thoughts and reactions during the studies. It was evident from these comments that a number of them were purposely seeking a concept during the second (random) phase of concept creation that was significantly different to that which they had produced in the first (non-random) phase. This was not something that had been anticipated from the start of the study and so there was no procedure in place to test for order effect on concept creation. It is conceivable that, had the sequence of activities been reversed (i.e. random followed by non-random), the designers might have been influenced differently. For example, some may have attempted to manually create concepts that were different to those they had created randomly. Alternatively, they may have attempted to recreate or refine one of the concepts that they had created randomly. One of the key attributes of the random CAD tool is the element of surprise that accompanies each new concept it creates. There were no findings to suggest that surprises occurring sooner or later in the concept creation process were linked to feelings of disappointment or success. While the order effect might have been different, it is reasonable to suggest that the net value of the tool's random capability would have been similar. However, it would be preferable for the designer to have the ability to interchangeably switch between random and non-random modelling techniques for the purpose of parametric refinement and subsequent inspiration. This would therefore seem to be a logical proposition for any further iterations of a CAD tool of this nature.

It is evident that in both the exploratory and main studies, 'Like and Dislike' provided the more consistent indicator of aesthetic preference. It was generally apparent that the strength of emotional response could influence the degree to which someone liked or disliked a concept. However, in some cases, both a strong and weak emotional response was indicated by different participants for the same concept.

vi. Typicality of product design concepts

Two of the least liked concepts from the Primary phase were amongst the most atypical and non-functional examples of a vase (i.e. p6v2a and p9v2a). Their low profile and squashed appearance meant that they did not appear capable of functioning in the way most people would expect. Respectively, some of the most liked concepts were amongst the most typical (p7v2a, p4v2b and p5v2b) possessing a base capable of holding water and a narrowing neck to support stems, both attributes of common vases. The most liked concept of the primary phase (p2v1a) even exhibited some plant-like qualities. On the whole, the results appear to support the idea that while novelty in design is an affective quality, when it is at the expense of fundamental requirements (such as function) a negative emotional response is likely. It is therefore essential that any element of randomness incorporated into the creative process is carefully gauged according to the degree of typicality that might be deemed necessary.

4.4.9 Summary

The first part of the main study was devised in order to gain a better understanding of how designers perceive the application of a pseudo-random CAD tool. The first null hypothesis surmised that designers would not find such a tool useful when attempting to create product design concepts to elicit emotional responses. However, the results of the main study indicate that on the whole, the designers found the CAD tool to be more useful than the non-random (manual) version.

The results of both phases of the study found that more designers preferred using the random CAD tool than the manual version. It also found that more designers preferred the vase concepts they created using the random CAD tool and that most considered these to be more original and surprising than the ones created using the manual CAD tool. In both the primary and verification phases of the study, the designers considered the strength of emotional responses elicited by their concepts to be similar regardless of creation method. On this evidence, the first null hypothesis is refuted.

The second part of the main study looked at other people's perceptions towards the vase concepts created by the designers. In particular, whether people have a tendency to prefer product design concepts created using a random or non-random CAD tool and whether the creation method affects the strength or type of emotional responses. A second null hypothesis presumed that the concepts would not be regarded differently. Of course, each concept created during the study was the result of many decisions on the designers' part regardless of the CAD tool used. The randomly created concepts were subject to appraisal and selection by the designers before they were presented in the questionnaire. In addition, the designers created five concepts manually before selecting the one to proceed to part two. This means that the individual designers' influence on the outcomes of the study should not be ignored.

However, the final collective values for all concepts created in each phase imply that the randomly created concepts were liked more overall than the manually created ones. The same values indicate that the strength of emotional response was inconsistent between study phases. The results of direct comparisons between the most liked concepts from each phase were consistent with their original concept appraisals. That is, the comparisons indicated that the top performing manually created concept elicited the strongest overall emotional response and was the more surprising, desirable and stimulating. Despite this, the top performing randomly created concept was also found to be the more surprising and desirable. The second null hypothesis is therefore partially upheld, since there was no evidence to suggest that the method of concept generation alone influences whether a product design concept will elicit a strong or weak emotional response.

4.9 Chapter Summary

The overall methodology sought to refine and, ultimately, answer the research questions. To that end, it can largely be regarded as having been successful. The pilot study established themes for further research and raised some important issues for consideration in subsequent studies. The exploratory study provided preliminary data regarding the use of a CAD tool for design and emotion. As a result of this study, progress was made that led to the development of a prototype random CAD tool which subsequently facilitated the culmination of this PhD research project.

The main study addressed elements of the research question using a variety of methods. The design activity demonstrated that on the whole, designers are receptive to the idea of a CAD tool capable of generating seemingly random product design concepts. The productivity benefits of being able to reduce the time required to generate multiple design concepts are quite apparent.

The appraisal activity demonstrated that, in terms of the concepts produced, there are few drawbacks to using random concept generation techniques early in the design process. While certain concepts created during the main study exhibited the ability to elicit a strong emotional response, there was little to suggest that this was as a result of the means of concept creation.

5. Conclusions and Recommendations

5.1 Introduction

This chapter concerns the key findings of the overall PhD research project. In particular, it discusses the results of the studies in relation to the research question. Further to this, it also provides proposals for further potential research and suggestions for development and refinement.

5.2 Conclusions

Throughout this research, the aim has been to find a means by which designers could exploit an affective CAD tool during concept development. Initially, this started out as a CAD tool driven by verbal descriptors. However the emphasis direction changed during the course of the research, eventually seeking to exploit randomness as a tool to help designers elicit positive emotional responses from their design concepts.

The pilot study sought to investigate how people respond emotionally to images of products when they encounter them for the first time. The results of that study indicated that people can experience a variety of emotional responses to the same design products, depending on their needs, expectations and experiences. However, it also indicated that surprises experienced in relation to an encounter with a product design may help to leave a lasting impression.

The exploratory study tested the output of an initial CAD tool to see whether a range of positive and negative emotional responses could be elicited from simple CAD representations of product design concepts. According to the results, the table concepts used in the study did elicit a range of emotional responses, albeit predominantly negative. These concepts were highly simplified and typical of the product genre. As a result they could not be considered particularly novel. The most atypical examples were the least liked and this is likely due to their proportions, which was the only major differentiating factor. The atypical proportions could have been perceived as having impaired functional attributes, hence the strong negative emotional responses. The more typical proportions were highly functional, but more predictable. As a result, it could be implied that this lack of novelty also impeded the positive emotional responses elicited by those concepts.

Is a pseudo-random CAD tool an effective way of generating affective product design concepts?

Based on the results of the main study, a pseudo-random CAD tool was found to be an effective method of generating a breadth of product design concepts. This, coupled with a means of cross referencing concept appraisal feedback with geometric data, gave a good indication of how particular features and characteristics were perceived. In practise, the designer's role then becomes one of determining which overall concepts are capable of eliciting the most positive emotional response. The designer's ability to extrapolate the most favourable concept from the information available remains a key factor in determining a product design's aesthetic appeal.

a. What differences can be observed between the likeability of randomly and non-randomly generated concepts?

Little difference was observed once filtering via selection had occurred by the designers. Without this however, it is likely that a much broader range of concepts would have included many potentially unsuitable concepts. The breadth of possible concepts is constrained by the parametric variables used to determine the CAD tool's capabilities. Narrowing this range limits both the likelihood of unsuitable concepts, but also the combinations of parameters capable of producing unexpected or surprising results.

b. What relationships can be observed between the strength of elicited emotional response and the likeability of a design concept?

It was clear from the results of the exploratory study that the nature of any emotional response in relation to a product design concept must be positive. However, where the response is neutral the relationship is less apparent. A number of concepts produced during the main study were indicated by different participants to have elicited the strongest or weakest emotional response. However, few concepts were found to have elicited both the strongest *and* weakest emotional response, suggesting that there was at least some consistency between participants. The results of the main study also indicate that a highly likeable concept need not elicit a *strong* emotional response, albeit preferable.

c. Does the strength of elicited emotional responses differ between randomly and non-randomly created concepts?

In the main study, people's perceptions were gauged in relation to concepts created using both a random and non-random CAD tool. It was found that, in general, the creation method alone did not appear to affect the strength or type of emotional response. The capabilities of the CAD tools in conjunction with the designers' ability to evaluate were sufficient to ensure that the concepts were comparable. With regards to the relationship between emotional response and concept likeability, the results suggest that overall the most liked concepts also elicited the strongest emotional response while the least liked concepts elicited the weakest emotional responses. There were a minority of anomalous exceptions to this however, observed in the verification phase where some of the most liked and disliked concepts elicited a significant number of both the strongest and weakest emotional responses.

d. Does the application of a pseudo-random CAD tool affect the designers' experience?

The main study took into consideration the views and experiences of the designers of products as well as those perceiving those product designs. Further to this, it tested the application of a pseudo-random CAD tool for the purpose of creating product design concepts to elicit emotional responses. The study found that the designers enjoyed the experience and considered the random capabilities to be beneficial and useful during concept generation. Since pleasure, surprise and anticipation are recognisable elements of play, this lends support to the idea that play can be an important, even integral part of the creative process.

e. **Can the CAD tool be used to identify particular geometric features that elicit strong emotional responses?**

Parametric values of the concepts produced during each phase of the main study were extracted directly from the CAD software (3DSMax). These values related to proportion and the variables used in the application of each modifier. Analysis of the concepts' geometric parameters identified that certain characteristics were preferable while others, though capable of eliciting a strong emotional response (e.g. Twist modifier), were found to be less favourable. It is clear that the latter should be avoided where the design objective is to create a visually appealing concept. The ability to scrutinise this information in conjunction with the results of the concept appraisals provided a means of appraising the effect of a concept's geometric features. It is therefore likely that equivalent information could be used to provide designers with a means of refining other design concepts in this way.

5.3 Discussion of the Findings

This PhD research project was conducted in three stages, with each building on the one before to refine and ultimately answer the research question. In conjunction, a process of CAD tool creation and experimentation was adopted in an effort to capitalise on the findings of each study as they were completed. The findings support the notion of a random CAD tool for concept generation. However, consideration must inevitably be given to the broad context of product design, in which the constantly evolving breadth of product types and derivatives can lead to countless conceivable features and forms. As a result, a general purpose tool that can be of genuine use to designers without the need for considerable modification (to cater for individual product types) seems highly unlikely. Every product type would need a specific set of parameters and each derivative would need additional definitions to create an appropriate breadth of suitable design concepts. As a product's complexity increases, so too does the number of possible parameters and permutations. Each additional feature effectively becomes a concept in its own right. Where parametric definition is undertaken manually this would mean that more time may be spent defining parameters than creating design concepts. It is likely that a CAD tool is only beneficial where the time necessary to prepare its capabilities does not exceed the time required to create a suitable concept using conventional techniques.

The main benefits of incorporating randomness in the design process are the breadth of output and the speed of concept creation once all parameters have been defined. Randomness could be used to build an extensive database of parts in a relatively short space of time. If each individual feature from which a product design is comprised is considered a concept itself, then it is conceivable that randomness could be applied efficiently in the creation of those features. For example, the design of a table leg could be randomly created, regardless of the table's overall design and configuration. Designers could select parts for further refinement and development, depending on their particular requirements. The fewer parametric variables required, the shorter the set-up time.

In an educational context the CAD tool has proven to offer insight to relatively inexperienced designers. Many of the designer participants that contributed to the main study found the breadth of possibilities made apparent by the random CAD tool to be enlightening and inspirational. In a commercial context however, it is likely that the designer's experience will be significantly greater. Where this is the case it is possible that such a tool's value would probably be limited to the inspiration and initiation of product design concepts for further development.

5.4 Recommendations

Following analysis of the results from the studies undertaken, a number observations were made that could provide the basis for further research in this area.

- Aesthetic features

The motivation behind participants' reported emotional responses was not recorded during the study and might have provided further insight as to why particular concepts were perceived in the way they were. For example, did the twist modifier used in the Vase Maker CAD tool produce an effect that the participants associated with an unfashionable style, or was it perceived as undesirable for other reasons? When defining the CAD tool parameters it is necessary to identify geometric features and characteristics appropriate to the product type and the market requirements. An understanding of the product design context is imperative when determining the CAD tool's capabilities. Further research into the specific types of features capable of eliciting desirable emotional responses for a given product type would therefore be recommended prior to the development of any CAD tool for the purposes of affective augmentation.

- Participant diversity

The main study used comparable groups of participants in the form of undergraduate Industrial Design students from Bournemouth University. Demographic data was collected for this study. This indicated that their ages varied by one or two years overall and they were mostly white and British. Most of the designer participants were male and more of the appraisers were male than female. The findings can only really be regarded as representative within these boundaries. Widening the scope might have produced different results. For example, it might have been found that a group of appraisers from a different demographic group would have perceived the effect of the twist modifier as more attractive in the context of a vase. Further research into the impact of social and cultural diversity on the way product concepts are perceived would provide useful insight for designers that could inform and refine the way the CAD tool is set up prior to concept generation.

- CAD tool prototype development

The CAD tool prototypes used in the research were relatively simple and had significant restrictions. These included the breadth of possible geometric features and the types of products they could generate concepts for. It is therefore suggested that further research undertaken to investigate the effect of using randomly generated features in a variety of other products would be beneficial to software developers, designers and design researchers. This research could include, for example:

- UI development to improve the designer's experience.
- Artificial intelligence assisted parametric definition to reduce the time required to update or alter the CAD tool's concept generation capabilities.
- A hybrid CAD tool combining elements of the random and non-random capabilities.
- Morphology capabilities to combine aspects of two or more concepts.
- Testing of a parts creation tool using random variables and the formulation of a parts database for product designers.
- Enhanced analytics to appraise and benchmark concepts against specific affective criteria.
- The impact of order effect (random and non-random) on the concept creation process.

- Parametric analysis of preference and strength of emotional response

The method of data collection used in the main study may be regarded as having had two disadvantages. The first of these was that intermediate concept rankings could only be achieved by counting the number of selections for 'liked-most' and 'liked-least' or SER and WER. Therefore a concept that only received one or two selections might appear to elicit an almost neutral emotional response, even though for a minority of participants the opposite was actually true.

The second was that there was no predetermined scale against which participants could measure their degree of preference. This meant that for one individual the perceived margin between respective concepts could have been much larger or smaller than that of another's. Similarly, the perceived strength of an emotional response will be subjective, depending on what one might expect in relation to the given context and one's propensity to perceive emotions. When compared to the maximum possible strength of emotions (e.g.

such as might be elicited during a critical or dangerous situation), all the responses elicited by the concepts could be considered weak. Furthermore, it might be harder to identify weak emotional responses than strong ones due to the reduced emotional stimulation. Further investigation into a means of helping individuals to more accurately appraise and report these parameters could be of interest to design researchers as a means of recording consistent, accurate data in future studies.

5.5 Chapter Summary

Products capable of eliciting strong, positive emotional responses are generally highly desirable, so a tool that can help designers achieve that objective will likely be well received. The benefit of such a tool relies on its ability to create affective concepts in relatively little time. Therefore, its value is judged by the time saved (which is directly proportional to the time spent preparing the tool in the first place) and the affectiveness of the concepts produced. Where the preparation of the CAD tool requires considerable time and effort its perceived value may fall, particularly in highly dynamic commercial contexts where time can be a significant constraint. A prototype pseudo-random CAD tool was found to be beneficial in generating unexpected results that could provide inspiration for subsequent development. It has been demonstrated that with: careful planning; a good understanding of the product context and an efficient mechanism for parametric definition, designers can successfully exploit the use of random variables for the purposes of product design concept generation.

References

Aaker, J. L., 1999. The malleable self: The role of self-expression in persuasion. *Journal of Marketing Research,* 36(February), pp. 45-57.

Acar, B., 1996. A new model for design process. *Proceeding of the Institution of Mechanical Engineers,* Volume 210, p. 135.

Bennet, D. J., 1999. *Randomness.* London, Harvard University Press.

Boatwright, P. & Cagan, J., 2010. *Built to Love: Creating products that captivate customers.* San Francisco: Berrett-Koehler.

Bonnardel, N. & Zenasni, F., 2010. The Impact of Technology on Creativity in Design: An Enhancement?. *Creativity and Innovation Management,* 19(2), pp. 180-191.

Boulez, P., Noakes, D. & Jacobs, P., 1964. Alea. *Perspectives of New Music,* 3(1), pp. 42-53.

Britten, N., 1995. Qualitative Research: Qualitative interviews in medical research. *British Medical Journal,* Volume 311, pp. 251-253.

Brown, T., 2008. *Tales of creativity and play.* [Online]
Available at: https://www.ted.com/talks/tim_brown_on_creativity_and_play
[Accessed 12 January 2016].

Campbell, A. & Pisterman, S., 1996. A Fitting Approach to Interactive Service Design: THE IMPORTANCE OF EMOTIONAL NEEDS. *DMI Review,* 7(4), pp. 10-14.

Chitturi, R., 2009. Emotions by Design. *International Journal of Design,* 3(2), pp. 7-17.

Ciccarelli, S. K. & White, J. N., 2012. *Psychology.* 3 ed. s.l.:Prentice Hall.

Cobley, P. & Jansz, L., 1999. *Introducing Semiotics.* Cambridge: Icon Books Ltd..

Crozier, R., 1994. *Manufactured Pleasures - Psychological responses to design.* Manchester: Manchester University Press.

Damasio, A. R., 1995. *Descartes' error: emotion, reason, and the human brain.* s.l.:Avon Books.

De Bono, E., 1990. *Lateral Thinking: A Textbook of Creativity.* London: Penguin Books.

de Moraes Cardoso, C. J., 2016. *SUNYWCC 2D Design.* [Online]
Available at: http://sunywcc2ddesign.com/practice-1-design-process-chance
[Accessed 25 August 2016].

Demirbilek, O. & Sener, B., 2003. Product design, semantics and emotional response. *Ergonomics,* Volume 46, pp. 1346-1360.

Demir, E., Desmet, P.M.A. & Hekkert, P., 2009. Appraisal patterns of emotions in human-product interaction,. *International Journal of Design,* 3(2), pp. 41-51.

Desmet, P., 2002. *Designing Emotions.* Delft: Delft University.

Desmet, P., 2004. *A Basic Typology of Product Emotions.* Ankara, Design and Emotion Society.

Desmet, P. & Hekkert, P., 2007. Framework of product experience. *International Journal of Design,* 1(1), pp. 57-66.

Dhar, R. & Wertenbroch, K., 2000. Consumer choice between hedonic and utilitarian goods. *Journal of Marketing Research,* 37(1), pp. 60-71.

Dorst, K., 2001. Creativity in the design process: co-evolution of problem–solution. *Design Studies,* Volume 22, pp. 425-437.

Dutton, D., 2003. Aesthetics and Evolutionary Psychology. In: J. Levinson, ed. *The Oxford Handbook for Aesthetics.* New York: Oxford University Press.

Dyer, B. T. et al., 2002. Design Semiotics: 'Arty'-ficial Intelligent CAD. In: M. Evatt & E. Brodhurst, eds. *Sharing experience in engineering design : proceedings of the 24th SEED Annual Design Conference and 9th National Conference on Product Design Education, 3rd-4th September 2002, Coventry University, Coventry, UK.* Bury St Edmunds: Professional Engineering, pp. 221-228.

Eagle, A., 2016. *Chance versus Randomness.* [Online]
Available at: https://plato.stanford.edu/archives/win2016/entries/chance-

randomness/
[Accessed 22 5 2017].

Eberle, S., 2014. The Elements of Play: Toward a Philosophy and a Definition of Play. *Journal of Play,* 6(2), pp. 214-232.

Ellison, C., 1995. Cryptographic Random Numbers. In: *IEEE P1363.* s.l.:IEEE, p. Appendix E.

ENGAGE, 2005. *ENGAGE (2005), European Project on Engineering Emotional Design Report of the State of the Art,* Valencia: s.n.

Epstein, S., 1994. Integration of the cognitive and psychodynamic unconscious. *American Psychologist,* 49(8), pp. 709-724.

Eves, W. & Hewitt, J., 2009. *Semiotics, Design Character Language.* Barcelona, Institution of Engineering Designers.

Eves, W. R., 1997. *The Colour Concept Generator: A Computer Tool to Propose Colour Concepts for Products.* Bournemouth: Bournemouth University.

Fairhead, H., 2013. *ERNIE - A Random Number Generator.* [Online]
Available at: http://www.i-programmer.info/history/machines/6317-ernie-a-random-number-generator.html
[Accessed 2 June 2017].

Farlex, 2016. *The Free Dictionary.* [Online]
Available at: http://www.thefreedictionary.com/Aleatoricism
[Accessed 2016].

French, M., 1999. *Conceptual Design for Engineers.* 3 ed. London: Springer-Verlag London.

Friida, N., 1986. *The Emotions.* Cambridge: Cambridge University Press.

Giannini, F. & Monti, M., 2002. *An innovative approach to aesthetic design.* s.l., Staffordshire University Press.

Giannini, F. & Monti, M., 2002. CAD tools based on aesthetic properties. *Eurographics Italian Chapter.*

Gonzalez , M. E. Q., 2005. Creativity: Surprise and abductive reasoning. *Semiotica,* 153(1), pp. 325-341.

Govers, P. C. & Mugge, R., 2004. *'I Love My Jeep, Because It's Tough Like Me', The Effect of Product-Personality Congruence on Product Attachment.* Ankara, Turkey, The Design and Emotion Society.

Graham, I., 2012. *EvoShape.* [Online]
Available at: http://www.evoshape.co.uk/
[Accessed 29 June 2018].

Graham, I. J., Case, K. & Wood, R. L., 2001. Genetic algorithms in computer-aided design. *Journal of Materials Processing Technology,* 117(1-2), pp. 216-221.

Hannah, G. G., 2002. *Elements of Design; Rowena Reed Kostellow and the Structure of Visual Relationships.* New york: Princetown Architectural Press.

Hassenzahl, M., 2004. The Interplay of Beauty, Goodness, and Usability in Interactive Products. *Human-Computer Interaction,* Volume 19, pp. 319-349.

Hekkert, P., Snelders, D. & van Wieringen, P. C., 2003. 'Most advanced, yet acceptable': Typicality and novelty as joint predictors of aesthetic preference in industrial design. *British Journal of Psychology,* Issue 94, pp. 111-124.

Hemmings, R. M. L., 2005. *Unpredictable Popular Music: History, Praxis, Perception: Cryptography, Serialism, Pseudorandom Generation, Chance, Improvisation and Infinite Monkeys,* s.l.: De Montford University.

Hiort af Ornas, V. & Karlsson, M., 2004. *Causes of Emotive Responses to Artefacts.* Ankara, s.n.

Hjelm, S. I., 2002. *Semiotics in Product Design,* s.l.: Stockholm University.

Hsiao, S.-W. & Wang, H.-P., 1998. Applying the semantic transformation method to product form design. *Design Studies,* 19(3), pp. 309-330.

Hurst, K., 1999. *Engineering Design Principles.* 1 ed. London: Arnold.

Jackson-Pollock.org, 2011. *Jackson Pollock: Biography, Paintings and Quotes.* [Online]

Available at: http://www.jackson-pollock.org/
[Accessed 17 August 2016].

James, W., 1890. *The Principles of Psychology.* Cambridge: Harvard University Press.

Jordan, P., 2002. *How to make Brilliant Stuff that People Love and Make Big Money out of it.* Chichester: Wiley & Sons.

Karahanoğlu, A., 2009. Consumers’ Emotional Responses to Brands and Branded Products. *Design Principles and Practices: An International Journal,* 3(1), pp. 323-340.

Khalid, H. & Helander, M., 2006. Customer emotion needs in product design. *Concurrent Engineering: Research and Applications,* 14(3), pp. 197-206.

Kostelanetz, R., 2003. *Conversing with Cage.* New York: Routledge.

Krippendorff, K. & Butter, R., 1984. Product semantics: Exploring the symbolic qualities of form.. *The Journal of the Industrial Designers Society of America,* 3(2), pp. 4-9.

Krish, S., 2011. A practical generative design method. *Computer-Aided Design,* Volume 43, pp. 88-100.

Lama, S., Johnson, C., Maffei, K. & Bousquet, M., 2007. *3ds Max Maxscript Essentials.* Oxford: Elsevier.

Lazaraus, R., 1991. *Emotion and Adaptation.* Oxford: Oxford University Press.

LeDoux, J., 1996. *The Emotional Brain: The Mysterious Underpinnings of Emotional Life.* New York: Simon & Schuster.

Lenau, T. & Boelskifte, P., 2005. Product search through the use of semantic properties. *Design Communication (UIAH Working Paper),* Volume F30, pp. 11-23.

Leong, T. W., Vetere, F. & Howard, S., 2006. *Randomness as a Resource for Design.* Pennsylvania, ACM New York, pp. 132-139.

Lindgaard, G., Fernandes, G., Dudek, C. & Brown, J., 2006. Attention web designers: You have 50 milliseconds to make a good first impression!. *Behaviour and Information Technology,* 25(2), pp. 115-126.

Ludden, G. D., Hekkert, P. & Schifferstein, H. N., 2006. *Surprise and Emotion.* s.l., s.n., pp. 1-13.

Lumography, 2017. *Lumography.* [Online]
Available at:
https://2.cdn.lomography.com/a3/19dc01b27edbcc8318ffbad19bcbd07865ce66/1818x1228x2.jpg?auth=e35c73b882a7a29e933d1a1c719fda7700bbf2ce
[Accessed 20 January 2017].

Masson, A., 1924. *Wikipedia.* [Online]
Available at: https://en.wikipedia.org/wiki/Andr%C3%A9_Masson
[Accessed 24 January 2017].

McCormack, J. & Cagan, J., 2004. Speaking the Buick language: capturing, understanding and exploring brand identity with shape grammars. *Design Studies,* 25(1), pp. 1-29.

McCormack, J., Dorin, A. & Innocent, T., 2004. *Generative Design: a paradigm for design research.* Melbourne, Design Research Society.

McDonagh, D., Hekkert, P., van Erp, J. & Gyi, D., 2004. *Design and Emotion.* New York: Taylor and Francis.

McDougall, W., 1908. *An Introduction to Social Psychology.* London: Methuen & Co..

Minsky, M., 2006. *Emotion Machine.* s.l.:Simon & Schuster.

Muller, W. & Pasman, G., 1996. Typology and the organization of design knowledge. *Design Studies,* 17(2), pp. 111-113.

Nagamachi, M., 1995. Kansei Engineering: A new ergonomic consumer-oriented technology for product development. *Industrial Ergonomics,* Volume 15, pp. 3-11.

Nagamachi, M., 2010. *Kansei/Affective Engineering.* s.l.:CRC Press.

Norman, D. A., 2003. *3 ways good design makes you happy.* [Online].

Norman, D. A., 2004. *Emotional Design: Why we love (or hate) everyday things.* Cambridge, MA: Basic Books.

Objectified. 2009. [Film] Directed by Gary Hustwit. s.l.: Plexi Productions.

Osgood, C., Tannenbaum, P. & Suci, G., 1957. *The Measurement of Meaning.* Urbana: University of Illinois Press..

Overbeeke, C. J. & Hekkert, P., 1999. *Proceedings of the first international conference on Design & Emotion.* Delft, the Netherlands, Delft University of Technology.

Pahl, G. & Beitz, W., 2007. *Engineering Design: A Systematic Approach.* 3 ed. London: Springer-Verlag.

Picard, R. W., 1997. *Affective Computing,* s.l.: M.I.T Media Laboratory Perceptual Computing Section.

Pollock, J., 1948. *Tate.* [Online]
Available at: https://www.tate.org.uk/art/artworks/pollock-summertime-number-9a-t03977
[Accessed 24 January 2017].

Pugh, S., 1991. *Total Design: Integrated Methods for Successful Product Engineering.* 2 ed. Harlow: Addison-Wesley Publishers Ltd..

Ratner, C., 2000. A cultural-psychological analysis of emotions. *Culture and Psychology,* Volume 6, pp. 5-39.

Reynolds, T., 2010. *Researching First Contact Emotional Responses to Products.* Trondheim, Institution of Engineering Designers.

Saunders, M., Lewis, P. & Thornhill, A., 2009. *Research methods of business students.* 5th ed. Harlow: Pearson Education.

Schütte, S., 2005. *Kansei Engineering in Development.* Linköping: Linköpings Universitet.

Séquin, C. H., 2005. CAD tools for aesthetic engineering. *Computer-Aided Design,* Volume 37, pp. 737-750.

Shavelson, R. J. & Bolus, R., 1982. Self-Concept: The Interplay of Theory and Methods. *Journal of Educational Psychology,* 74(1), pp. 3-17.

Sirgy, M. J., 1982. Self-concept in consumer behavior. *Journal of Consumer Behaviour,* Volume 9, pp. 287-300.

Smith, D., 2016. *Preoccupations.* [Online]
Available at: http://www.preoccupations.org/2004/04/aleatoric.html
[Accessed 3 July 2016].

Sooke, A., 2016. *iWonder: Why can't a four-year old paint a Pollock?.* [Online]
Available at: http://www.bbc.co.uk/guides/zqhgr82
[Accessed 6 June 2016].

Spillers, F., 2004. *Emotion as a cognitive artefact and the design implications for products that are perceived as pleasurable.* Ankara, Design and Emotion Society.

Stiny, G., 1980. An introduction to shape and shape grammars. *Environment and Planning B,* Volume 7, pp. 343-351.

Susagroup, 2014. *PrEmo: Measure Product Emotions.* [Online]
Available at: http://www.premotool.com/
[Accessed 18 May 2017].

The Dark Room, 2016. *The Dark Room.* [Online]
Available at: https://thedarkroom.com/what-is-lomography/
[Accessed 5 May 2016].

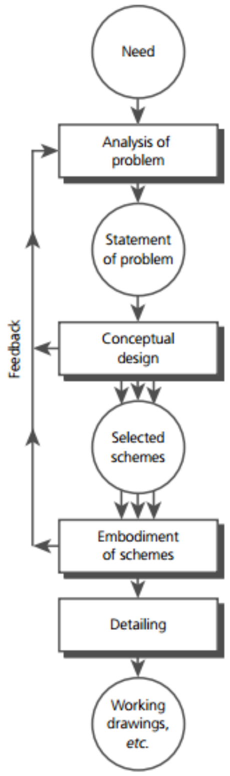
Tiger, L., 1992. *The Pursuit of Pleasure.* 4 ed. London: Transaction Publishers.

Veryzer, R. W. & Hutchinson, J. W., 2014. The Influence of Unity and Prototypicality on Aesthetic Responses to New Product Designs. *Journal of Consumer Research,* 24(4), pp. 374-385.

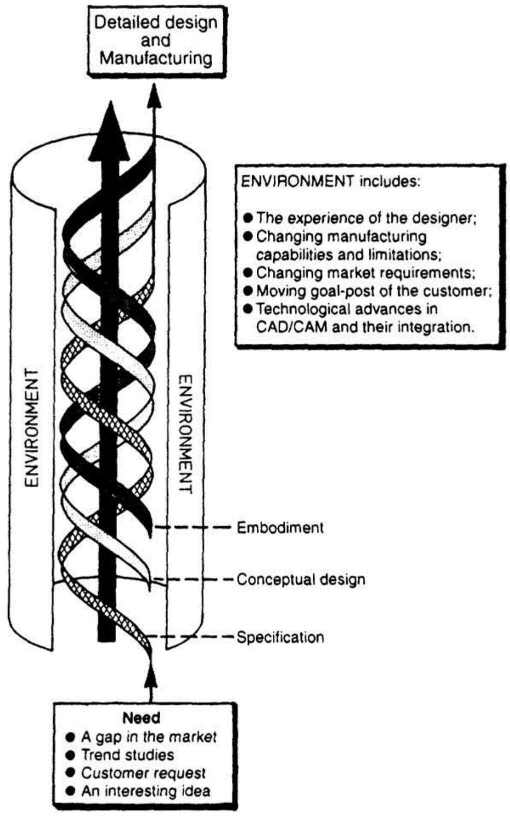
Xue, L. & Yen, C., 2007. Towards female preferences in design – A pilot study. *International Journal of Design,* 3(2), pp. 11-27.

Appendix: A - A selection of popular Design Process models

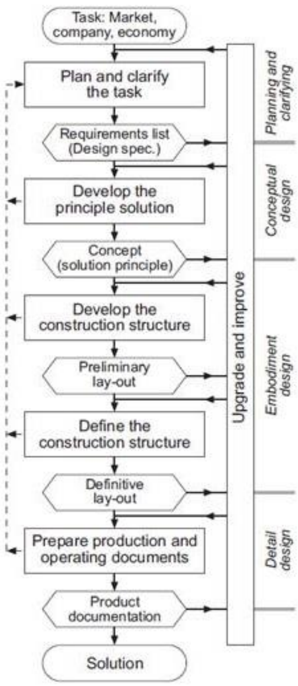
French, 1999:



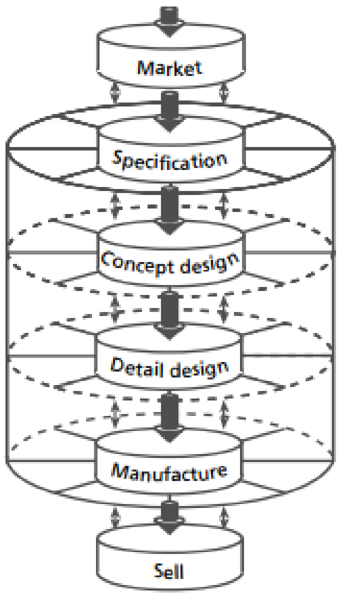
Acar, 1996:



Pahl and Beitz, 1984:



Pugh, 1991:



Appendix: B - Initial Research Ethics Checklists

Initial Research Ethics Checklist

Note: *All researchers* should complete this brief checklist to identify any ethical issues associated with their research. Before completing this, please refer to the BU *Research Ethics Code of Practice* which can be found www.bournemouth.ac.uk/researchethics. School Research Ethics Representatives (or Supervisors in the case of students) can advise on appropriate professional judgement in this review. A list of Representatives can be found at the aforementioned webpage.

Sections 1-5 must be completed by the researcher and Sections 6 – 7 by School Ethics Representative or Supervisor prior to the commencement of any research.

1 RESEARCHER DETAILS						
Name	Tim Reynolds					
Email	treynolds@bournemouth.ac.uk					
Status	☐ Undergraduate		☐ Postgraduate		☒ Staff	
School	☐ BS	☐ CS	☒ DEC	☐ HSC	☐ MS	☐ SM
2 PROJECT DETAILS						
Project Title	Enhancing Ergonomics in Product Design					
Project Summary *(including methodology, sample, outcomes etc)*	Initially a qualitative pilot study will be undertaken to develop a line of investigation into the emotional responses experienced by consumers is relation to their initial encounters with products.					
Proposed Start and End Dates of Data Collection	01/03/2010 to 01/05/2010					

3 ETHICS REVIEW CHECKLIST – PART A			
I	Has a health & safety evaluation / risk assessment been conducted?	☒ Yes	☐ No
II	Is approval from an external Research Ethics Committee (e.g. Local Research Ethics Committee (REC), NHS REC) required/being sought?	☐ Yes	☒ No
III	Is the research solely literature-based?	☐ Yes	☒ No
IV	Does the research involve the use of any dangerous substances, including radioactive materials?	☐ Yes	☒ No
V	Does the research involve the use of any potentially dangerous equipment?	☐ Yes	☒ No
VI	Could conflicts of interest arise between the source of funding and the potential outcomes of the research? (see section 8 of BU Research Ethics Code of Practice).	☐ Yes	☒ No
VII	Is it likely that the research will put any of the following at risk:		

	Living creatures?	☐ Yes	☒ No
	Stakeholders?	☐ Yes	☒ No
	The environment?	☐ Yes	☒ No
	The economy?	☐ Yes	☒ No
VIII	Does the research involve experimentation on any of the following:		
	Animals?	☐ Yes	☒ No
	Animal tissues?	☐ Yes	☒ No
	Human tissues (including blood, fluid, skin, cell lines)?	☐ Yes	☒ No
	Genetically modified organisms?	☐ Yes	☒ No
IX	Will the research involve prolonged or repetitive testing, or the collection of audio, photographic or video materials?	☒ Yes	☐ No
X	Could the research induce psychological stress or anxiety, cause harm or have negative consequences for the participants or researcher (beyond the risks encountered in normal life)?	☐ Yes	☒ No
XI	Will the study involve discussion of sensitive topics (e.g. sexual activity, drug use, criminal activity)?	☐ Yes	☒ No
XII	Will financial inducements be offered (other than reasonable expenses/ compensation for time)?	☐ Yes	☒ No
XIII	Will it be necessary for the participants to take part in the study without their knowledge / consent at the time?	☐ Yes	☒ No
XIV	Are there problems with the participant's right to remain anonymous?	☐ Yes	☒ No
XV	Does the research *specifically* involve participants who may be vulnerable?	☐ Yes	☒ No
XVI	Might the research involve participants who may lack the capacity to decide or to give informed consent to their involvement?	☐ Yes	☒ No

4 ETHICS REVIEW CHECKLIST – PART B	
Please give a summary of the ethical issues and any action that will be taken to address these. If you believe there to be no ethical issues please enter "NONE" into the box.	
Ethical Issue	Action
Collection and storage of audio/visual material.	Participants will not be visibly identifiable form the recorded material. Data will be stored on the researcher's office PC while it is analysed, and for no longer than 5 years in total.

5 STATEMENT – to be signed by Researcher
I believe that the information I have given in this form is correct. I have read and understood the BU Research Ethics Code of Practice, evaluated relevant insurance issues, performed a health & safety evaluation/ risk assessment and discussed any

issues/ concerns with a School Ethics Representative/ Supervisor.			
Signed		Date	01.02.2010
6 RECOMMENDATION ON THE RESEARCH PROJECT'S ETHICAL STATUS – to be signed by School Research Ethics Representative/ Supervisor			
Satisfied with the accuracy of the research project ethical statement, I believe that the appropriate action is:			
The research project proceeds in its present form		☐ Yes	☐ No
The research project proposal needs further assessment under the School Ethics procedure*		☐ Yes	☐ No
The research project needs to be returned to the research student for modification prior to further action*		☐ Yes	☐ No
** The School is reminded that it is their responsibility to ensure that no project proceeds without appropriate assessment of ethical issues. In extreme cases, this can require processing by the School or University's Research Ethics Committee or by relevant external bodies.*			
7 AFFIRMATION BY SCHOOL RESEARCH ETHICS REPRESENTATIVE/ SUPERVISOR			
I have read this Ethical Review Checklist and the BU Code of Practice and I can confirm that, to the best of my understanding, the information presented is correct and appropriate to allow an informed judgement on whether further ethical approval is required.			
Signed		Date	

Initial Research Ethics Checklist

Note: *All researchers* must complete this brief checklist to identify any ethical issues associated with their research. Before completing, please refer to the BU *Research Ethics Code of Practice* which can be found www.bournemouth.ac.uk/researchethics. School Research Ethics Representatives (or Supervisors in the case of students) can advise on appropriate professional judgement in this review. A list of Representatives can be found at the aforementioned webpage.

Sections 1-5 must be completed by the researcher and Section 6 by School Ethics Representative/ Supervisor prior to the commencement of any research.

1 RESEARCHER DETAILS						
Name	Tim Reynolds					
Email	treynolds@bournemouth.ac.uk					
Status	☐ Undergraduate		☐ Postgraduate		☒ Staff	
School	☐ BS	☐ AS	☒ SciTech	☐ HSC	☐ MS	☐ ST
Degree Framework & Programme	PhD					

2 PROJECT DETAILS	
Project Title	A Design Tool for the Affective Augmentation of Aesthetic Geometry
Project Summary *Sufficient detail is needed; include methodology, sample, outcomes etc*	The project concerns peoples emotional responses to product design concepts and how those responses are affected by geometric parameters. Methodology: 1) Develop 2 design tools: a) Non-random CAD tool b) Seemingly random CAD tool with time limit and no control interface Primary Phase: 2) Participant group 1 interact with a) to generate concept for emotional response with time limit and control interface. 3) Participant group 1: interact with b) to generate concept for emotional response with time limit. 4) Participant group 1: select up to 5 concepts with emotional response from both a) and b). 5) Record and evaluate parameters of each selected concept 6) Participants also complete questionnaire, re: response to using tool. 7) Generate seemingly random concepts incorporating feedback values 8) Record parameters - of generated concepts 9) Participant group 2: Rank concepts in conjunction with results from a) and b) 10) Repeat the above for verification and comparison 11) Evaluate responses
Proposed Start/End	Jan 2015 – May 2016
Project Supervisor	Prof. Siamak Noroozi/Dr Bob Eves

Framework Project Co-ordinator	Prof. Siamak Noroozi		
3 ETHICS REVIEW CHECKLIST – PART A			
I	Is approval from an external Research Ethics Committee (e.g. Local Research Ethics Committee (REC), NHS REC) required/sought?	☐ Yes	☒ No
II	Is the research solely literature-based?	☐ Yes	☒ No
III	Does the research involve the use of any dangerous substances, including radioactive materials?	☐ Yes	☒ No
IV	Does the research involve the use of any potentially dangerous equipment?	☐ Yes	☒ No
V	Could conflicts of interest arise between the source of funding and the potential outcomes of the research? (see section 8 of BU Research Ethics Code of Practice).	☐ Yes	☒ No
VI	Is it likely that the research will put any of the following at risk: Living creatures?	☐ Yes	☒ No
	Stakeholders?	☐ Yes	☒ No
	Researchers?	☐ Yes	☒ No
	Participants?	☐ Yes	☒ No
	The environment?	☐ Yes	☒ No
	The economy?	☐ Yes	☒ No
VII	Does the research involve experimentation on any of the following: Animals?	☐ Yes	☒ No
	Animal tissues?	☐ Yes	☒ No
	Human tissues (including blood, fluid, skin, cell lines)?	☐ Yes	☒ No
	Genetically modified organisms?	☐ Yes	☒ No
V111	Will the research involve prolonged or repetitive testing, or the collection of audio, photographic or video materials?	☐ Yes	☒ No
IX	Could the research induce psychological stress or anxiety, cause harm or have negative consequences for the participants or researcher (beyond the risks encountered in normal life)?	☐ Yes	☒ No
X	Will the study involve discussion of sensitive topics (e.g. sexual activity, drug use, criminal activity)?	☐ Yes	☒ No
XI	Will financial inducements be offered (other than reasonable expenses/ compensation for time)?	☐ Yes	☒ No
XII	Will it be necessary for the participants to take part in the study without their knowledge / consent at the time?	☐ Yes	☒ No
XII	Are there problems with the participant's right to remain anonymous?	☐ Yes	☒ No

XIV	Does the research *specifically* involve participants who may be vulnerable?	☐ Yes	☒ No
XV	Might the research involve participants who may lack the capacity to decide or to give informed consent to their involvement?	☐ Yes	☒ No

4 ETHICS REVIEW CHECKLIST – PART B

Please give a summary of the ethical issues and any action that will be taken to address these.

Ethical Issue: None	Action: None

5 RESEARCHER STATEMENT

I believe the information I have given is correct. I have read and understood the BU Research Ethics Code of Practice, discussed relevant insurance issues, performed a health & safety evaluation/ risk assessment and discussed any issues/ concerns with a School Ethics Representative/ Supervisor. I understand that if any substantial changes are made to the research (including methodology, sample etc), then I must notify my School Research Ethics Representative/ Supervisor and may need to submit a revised Initial Research Ethics Checklist. By submitting this form electronically I am confirming the information is accurate to my best knowledge.

Signed		Date	21.01.2015

6 AFFIRMATION BY SCHOOL RESEARCH ETHICS REPRESENTATIVE/ SUPERVISOR

Satisfied with the accuracy of the research project ethical statement, I believe that the appropriate action is:

The research project proceeds in its present form	☐ Yes	☐ No
The research project proposal needs further assessment under the School Ethics procedure*	☐ Yes	☐ No
The research project needs to be returned to the applicant for modification prior to further action*	☐ Yes	☐ No

** The School is reminded that it is their responsibility to ensure that no project proceeds without appropriate assessment of ethical issues. In extreme cases, this can require processing by the School or University's Research Ethics Committee or by relevant external bodies.*

Reviewer Signature	(Electronic)	Date	
Additional Comments			

Appendix: C - MaxScript Code for 'Table Builder' Prototype CAD tool

-- Clear old roll-outs

```
if ((tableRoll != undefined) and (tableRoll.isdisplayed)) do
		(destroyDialogtableRoll)
```

-- UI for Table Builder

```
rollouttableRoll "Table Builder"
		(
			group "Build"
				(
					spinnersld_Table_L "Table Length " type:#integer range:[300,2000,1200] tooltip:"Select Table Length" align:#left width: 100 across: 2
					spinnersld_Table_W "Table Width " type:#integer range:[300,2000,1000] tooltip:"Select Table Width" align: #left width: 100
					buttonbut_buildTable_R "Rectangle Table" tooltip:"Create the basic table" across: 3
					buttonbut_buildTable_E "Ellipse Table" tooltip:"Create the basic table" offset: [7,0]
					buttonbut_rebuildTable "Delete Table" tooltip:"Re-create your last table" offset: [4,0] enabled: false
				)
					buttonbut_sln "Slender" across: 2 tooltip:"Apply/Re-Apply a slender style to your table" align:#left across:3 offset: [10,14] enabled: false
					buttonbut_cls "Classic" tooltip:"Apply/Re-Apply a classis style to your table" align: #left  across:3 offset: [-25,14] enabled: false
					checkboxbut_smo "Smoothing ON/OFF" checked: false align: #left across: 3 height: 30 width: 75 offset: [177, -27] tooltip:"Apply a smoothing effect to the table legs" enabled: false
					buttonbut_chk "Chunky" across: 2 tooltip:"Apply/Re-Apply a chunky style to your table" across: 3 align:#left offset: [-73,-2] enabled: false
					buttonbut_got "Gothic" tooltip:"Apply/Re-Apply a gothic style to your table" across:3 offset: [-66,-2] align: #left enabled: false
					checkboxbut_dis "Distortion ON/OFF" checked: false align: #left across: 3 width: 75 height:30 offset: [177, -15] tooltip:"Apply a smoothing effect to the table legs" enabled: false
					buttonbut_dmp "Dumpy" across: 2 tooltip:"Apply/Re-Apply a dumpy style to your table" across: 3 align:#left offset: [-72,-2] enabled: false
					buttonbut_crv "Curvy" tooltip:"Apply/Re-Apply a curvy style to your table" across:3 offset: [-65,-2] align: #left enabled: false
					groupbox grp1 "Proportion" pos: [5,75] width: 85 height: 90 across: 3
					groupbox grp2 "Style" pos: [95,75] width: 85 height: 90
					groupbox grp3 "FX" pos: [185,75] width: 85 height: 90

			group "Modify"
				(
					slidersld_thth "Thickness" type:#float range:[1.01, 2, 1.2] tooltip: "Select the amount to thin/thicken the materials" across: 2 enabled: false
					slidersld_str "Leg Length/Position" type:#float range:[1.01, 4, 2] tooltip:"Select the amount to stretch, shorten, move or bend the legs" enabled: false
					buttonbut_T_thin "Thin Top" tooltip: "Thin Top Materials" across:4 width: 50 offset: [-5,0] enabled: false
					buttonbut_T_thick "Thick Top" tooltip: "Thicken Top Materials" across:4 width: 52 offset: [-10,0] enabled: false
					buttonbut_sho "Short Legs" tooltip:"Reduce leg height" across:4 width: 57 offset: [3,0] enabled: false
					buttonbut_str "Long Legs" tooltip:"Increase leg height" across:4 width: 55 offset: [5,0] enabled: false
					buttonbut_L_thin "Thin Legs" tooltip: "Thin Leg Materials" across:4 width: 50 offset: [-5,0] enabled: false
					buttonbut_L_thick "Thick Legs" tooltip: "Thicken Leg Materials" across:4 width: 54 offset: [-6,0] enabled: false
					buttonbut_in_leg "Legs in" across: 2 tooltip:"Move the legs towards the middle of the table" width: 55 enabled: false
					buttonbut_out_leg "Legs out" tooltip:"Move the legs outwards from the middle of the table" enabled: false
					slidersld_bend "- Bend Amount +" range: [-10, 10, 1] tooltip:"Select bend amount/direction" across: 2 enabled: false
					Slider sld_tap "- Taper Amount +" type: #float range:[-1, 0.5, -0.2] tooltip: "Select the Positive/Negative taper amount" align: #right offset: [5,0] enabled: false
					checkbuttonbut_bend "Bend Legs ON/OFF" across: 2 tooltip:"Bend the legs" across:2 checked: false align: #left offset: [2,0] enabled: false
					checkbuttonbut_tap "Taper Legs ON/OFF" tooltip: "Apply taper modifier" checked: false align: #right offset: [-7,0] enabled: false
```

```
)
-- Define Default Variables:
local z = 0
local f = 1.5
localth = 25
localrtlth = 50
localetlth = 30
locallh = 500
global o
globaltabletop
global tableleg1
global tableleg2
global tableleg3
global tableleg4

-- Create a rectangular default table
onbut_buildTable_R pressed do
(
tabletop = chamferbox length: sld_Table_L .value width: sld_Table_W .value height: th  fillet: f
tableleg1 = box length: rtlth width: rtlth height: -lhwidthsegs: 10 heightsegs: 100
tableleg1.pos = tabletop.pos + [(sld_Table_W .value/2)-100,(sld_Table_L .value/2)-100,z]
tableleg2 = box length: rtlth width: rtlth height: -lhwidthsegs: 10 heightsegs: 100
tableleg2.pos = tabletop.pos + [(sld_Table_W .value/2)-100,-(sld_Table_L .value/2)+100,z]
tableleg3 = box length: rtlth width: rtlth height: -lhwidthsegs: 10 heightsegs: 100
tableleg3.pos = tabletop.pos + [-(sld_Table_W .value/2)+100,(sld_Table_L .value/2)-100,z]
tableleg4 = box length: rtlth width: rtlth height: -lhwidthsegs: 10 heightsegs: 100
tableleg4.pos = tabletop.pos + [-(sld_Table_W .value/2)+100,-(sld_Table_L .value/2)+100,z]
rotate tableleg2 (angleaxis 90 [0,0,1])
rotate tableleg3 (angleaxis -90 [0,0,1])
rotate tableleg1 (angleaxis 180 [0,0,1])
#(tableleg1, tableleg2, tableleg3, tableleg4, tabletop).wirecolor = color 204 153 102
#(
sld_thth,
sld_str,
sld_bend,
sld_tap,
but_sln,
but_crv,
but_smo,
but_got,
but_cls,
but_dmp,
but_chk,
but_chk,
but_chk,
but_rebuildTable,
but_str,
but_sho,
but_in_leg,
but_out_leg,
but_T_thick,
but_T_thin,
but_L_thick,
but_L_thin,
but_tap,
but_bend,
but_dis).enabled = true
but_buildtable_R .enabled = false
but_buildtable_E .enabled = false
)
-- Create a default elliptical table
onbut_buildTable_E pressed do
(
tabletop = ellipse length: sld_Table_L .value width: sld_Table_W .value
addmodifiertabletop (Extrude ())
tableleg1 = cylinder length: tlth radius: etlth height: -lhwidthsegs: 10 heightsegs: 100 lengthsegs: 10
tableleg1.pos = tabletop.pos + [(sld_Table_W .value/4),(sld_Table_L .value/4),z]
tableleg2 = cylinder length: tlth radius: etlth height: -lhwidthsegs: 10 heightsegs: 100
tableleg2.pos = tabletop.pos + [(sld_Table_W .value/4),-(sld_Table_L .value/4),z]
tableleg3 = cylinder length: tlth radius: etlth height: -lhwidthsegs: 10 heightsegs: 100
tableleg3.pos = tabletop.pos + [-(sld_Table_W .value/4),(sld_Table_L .value/4),z]
tableleg4 = cylinder length: tlth radius: etlth height: -lhwidthsegs: 10 heightsegs: 100
tableleg4.pos = tabletop.pos + [-(sld_Table_W .value/4),-(sld_Table_L .value/4),z]
rotate tableleg2 (angleaxis 90 [0,0,1])
rotate tableleg3 (angleaxis -90 [0,0,1])
```

```
				rotate tableleg1 (angleaxis 180 [0,0,1])
				#(tableleg1, tableleg2, tableleg3, tableleg4, tabletop).wirecolor = color 204 153 102
				#(
					sld_thth,
					sld_str,
					sld_bend,
					sld_tap,
					but_sln,
					but_crv,
					but_smo,
					but_got,
					but_cls,
					but_dmp,
					but_chk,
					but_chk,
					but_chk,
					but_rebuildTable,
					but_str,
					but_sho,
					but_in_leg,
					but_out_leg,
					but_T_thick,
					but_T_thin,
					but_L_thick,
					but_L_thin,
					but_tap,
					but_bend,
					but_dis
					).enabled = true
				but_buildtable_R .enabled = false
				but_buildtable_E .enabled = false
			)
```

-- Delete Table

```
		onbut_rebuildTable pressed do
			(
				delete #(tableleg1, tableleg2, tableleg3, tableleg4, tabletop)
					#(
						sld_thth,
						sld_str,
						sld_bend,
						sld_tap,
						but_sln,
						but_crv,
						but_smo,
						but_got,
						but_cls,
						but_dmp,
						but_chk,
						but_chk,
						but_chk,
						but_rebuildTable,
						but_str,
						but_sho,
						but_in_leg,
						but_out_leg,
						but_T_thick,
						but_T_thin,
						but_L_thick,
						but_L_thin,
						but_tap,
						but_bend,
						but_dis).enabled = false
					#(but_smo, but_bend, but_tap, but_dis).checked = false
					but_buildtable_R .enabled = true
					but_buildtable_E .enabled = true
				)
```

--Proportion Slender

```
			onbut_sln pressed do
				(
					(
						for o in objects where classofo.baseobject == box do
							(
								scale o [0.75, 0.75, 1.25]
							)
```

```
					for o in objects where classofo.baseobject == cylinder do
						(
							scale o [0.75, 0.75, 1.25]
						)
					)
				scaletabletop [1,1, 0.75]
			)
```

-- Proportion Chunky

```
		onbut_chk pressed do
			(
				for o in objects where classofo.baseobject == box do
					(
						scale o [1.5, 1.5, 1]
					)
				for o in objects where classofo.baseobject == cylinder do
					(
						scale o [1.5, 1.5, 1]
					)
				scaletabletop [1,1, 1.5]
			)
```

--Proportion Dumpy

```
		onbut_dmp pressed do
			(
				for o in objects where classofo.baseobject == box do
					(
						scale o [2, 2, 0.75]
					)
				for o in objects where classofo.baseobject == cylinder do
					(
						scale o [2, 2, 0.75]
					)
				scaletabletop [1,1, 2]
			)
```

--Style classic

```
		onbut_cls pressed do
			(
				for o in objects where classofo.baseobject == box do
					(
						tap = taper amount: 0.1 curve: -1.5 center: [0, 0, tableleg1.height]
						addmodifier o tap
					)
				for o in objects where classofo.baseobject == cylinder do
					(
						tap = taper amount: 0.1 curve: -1.5 center: [0, 0, tableleg1.height]
						addmodifier o tap
					)
			)
```

--Style Gothic

```
		local dis
		onbut_got pressed do
			(
				for o in objects where classofo.baseobject == box do
					(
						tap = taper amount: 0.1 curve: -1.5 center: [0, 0, tableleg1.height]
						addmodifier o tap
						dis = NoiseModifier scale: 100 strength:[15,15,15]
						addModifier o dis
					)
				for o in objects where classofo.baseobject == cylinder do
					(
						tap = taper amount: 0.1 curve: -1.5 center: [0, 0, tableleg1.height]
						addmodifier o tap
						dis = NoiseModifier scale: 100 strength:[15,15,15]
						addModifier o dis
					)
			)
```

--Style Curvy

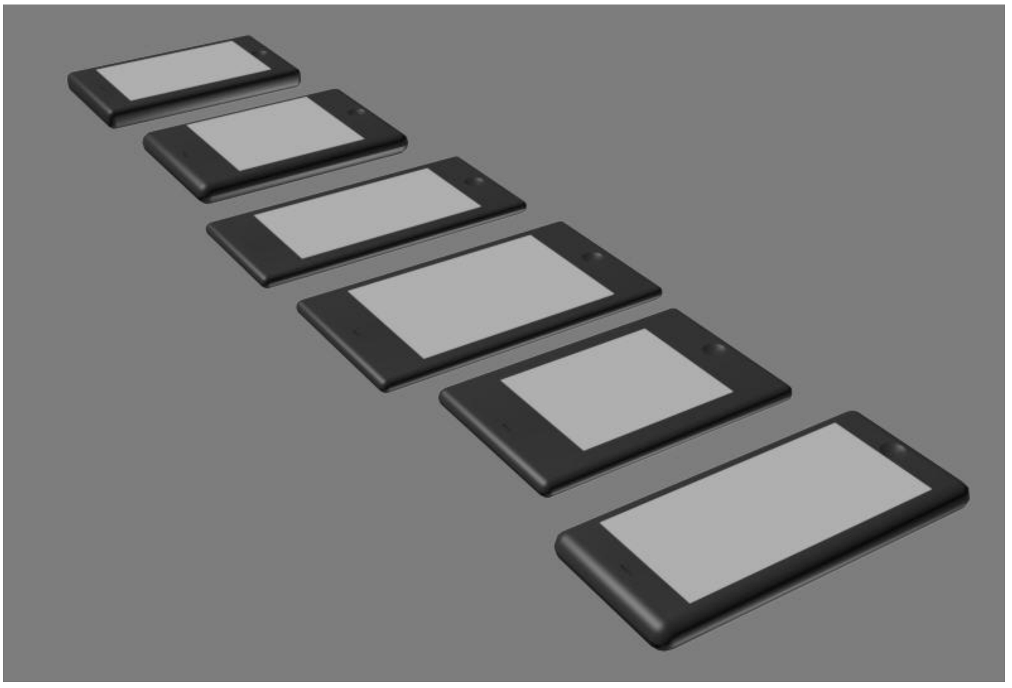
```
		onbut_crv pressed do
			(
				for o in objects where classofo.baseobject == box do
					(
						My_bend = bend bendangle: -10 benddir: 135
						addmodifier o My_bend
						tap = taper amount: 0.2 curve: 0.25 center: [0, 0, tableleg1.height /4]
						addmodifier o tap
```

```
                )
            for o in objects where classofo.baseobject == cylinder do
                (
                    My_bend = bend bendangle: -10 benddir: 135
                    addmodifier o My_bend
                    tap = taper amount: 0.2 curve: 0.25 center: [0, 0, tableleg1.height /4]
                    addmodifier o tap
                )
        )

-- Stretch/shorten legs
    onbut_str pressed do
        (
            for o in objects where classofo.baseobject == box do scale o [1, 1, sld_str .value]
            for o in objects where classofo.baseobject == cylinder do scale o [1, 1, sld_str .value]
        )
    onbut_sho pressed do
        (
            for o in objects where classofo.baseobject == box do scale o [1,1, 1/sld_str .value]
            for o in objects where classofo.baseobject == cylinder do scale o [1,1, 1/sld_str .value]
        )

--  Move legs
    onbut_in_leg pressed do
        (
            move tableleg1 [-2*sld_str .value , -2*sld_str .value, 0]
            move tableleg2 [-2*sld_str .value , 2*sld_str .value, 0]
            move tableleg3 [2*sld_str .value , -2*sld_str .value, 0]
            move tableleg4 [2*sld_str .value , 2*sld_str .value, 0]
        )
    onbut_out_leg pressed do
        (
            move tableleg1 [2*sld_str .value , 2*sld_str .value, 0]
            move tableleg2 [2*sld_str .value , -2*sld_str .value, 0]
            move tableleg3 [-2*sld_str .value , 2*sld_str .value, 0]
            move tableleg4 [-2*sld_str .value , -2*sld_str .value, 0]
        )

--  Bend Legs
    onbut_bend changed state do
        (
            if state == on then
                (
                    for o in objects where classofo.baseobject == box do
                        (
                            My_bend = bend bendangle: sld_bend .value
benddir: 135
                            addmodifier o My_bend
                        )
                    for o in objects where classofo.baseobject == cylinder do
                        (
                            My_bend = bend bendangle: sld_bend .value
benddir: 135
                            addmodifier o My_bend
                        )
                )
            else
                (
                    for o in objects do for my_bend = o.modifiers.count to 1 by -1  where
classofo.modifiers[my_bend] == bend do deleteModifier o my_bend
                )
            )
-- Thin/thicken materials
    onbut_L_thick pressed do
        (
            for o in objects where classofo.baseobject == box do scale o [sld_thth .value, sld_thth .value, 1]
            for o in objects where classofo.baseobject == cylinder do scale o [sld_thth .value, sld_thth
.value, 1]
        )
            onbut_T_thick pressed do
        (
            scaletabletop [1,1, sld_thth .value]
        )
            onbut_L_thin pressed do
        (
```

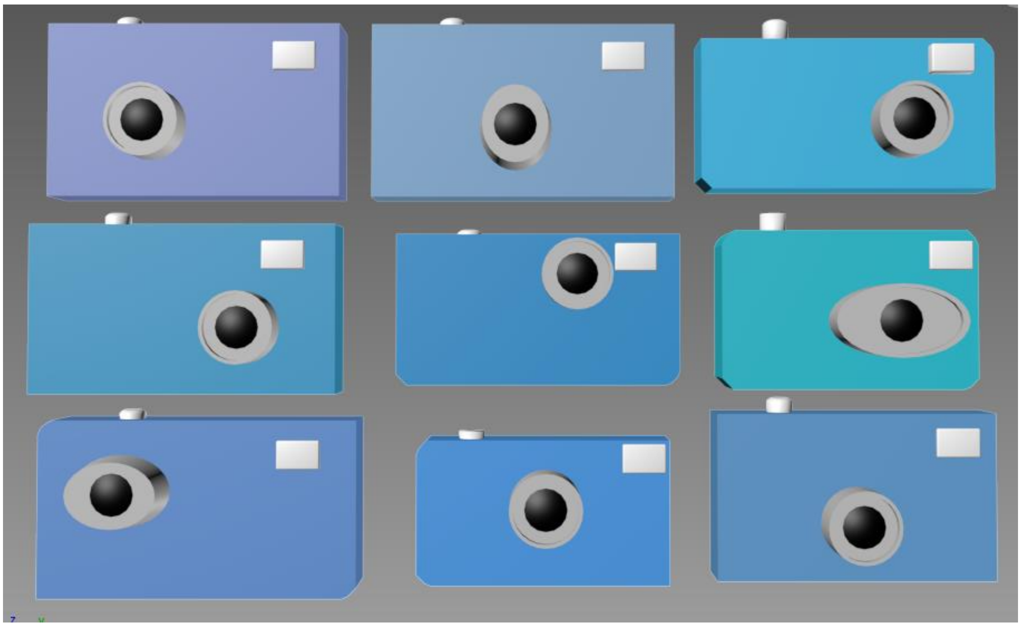
```
						for o in objects where classofo.baseobject == box do scale o [1/sld_thth .value, 1/sld_thth .value,
1]
						for o in objects where classofo.baseobject == cylinder do scale o [1/sld_thth .value, 1/sld_thth
.value, 1]
				)
						onbut_T_thin pressed do
				(
						scaletabletop [1,1, 1/sld_thth .value]
				)

--Taper Legs
			local tap
			onbut_tap changed state do
				(
						if state == on then
							(
								tap = taper amount: 0.3 curve: sld_tap .value center: [0, 0,
tableleg1.height /4]
								for o in objects where classofo.baseobject == box do addmodifier o tap
								for o in objects where classofo.baseobject == cylinder do addmodifier o
tap
							)
						else
							(
								for o in objects do for tap = o.modifiers.count to 1 by -1  where
classofo.modifiers[tap] == taper do deleteModifier o tap
							)
				)

-- Smooth Modifier
			localsmo
				onbut_smo changed state do
				(
						if state == on then
							(
								smo = meshsmooth subdivide: 0 strength: 0.01
								for o in objects where classofo.baseobject == box do addmodifier o smo
								for o in objects where classofo.baseobject == cylinder do addmodifier o
smo
							)
						else
							(
								for o in objects do for smo = o.modifiers.count to 1 by -1  where
classofo.modifiers[smo] == meshsmooth do deleteModifier o smo
							)
				)

-- Noise (Distortion) Modifier
			local dis
				onbut_dis changed state do
				(
						if state == on then
							(
								dis = noiseModifier scale: 100 strength:[15,15,15]
								for o in objects where classofo.baseobject == box do addmodifier o dis
								for o in objects where classofo.baseobject == cylinder do addmodifier o
dis
							)
						else
							(
								for o in objects do for dis = o.modifiers.count to 1 by -1  where
classofo.modifiers[dis] == noiseModifier do deleteModifier o dis
							)
				)
	)
createDialogtableRoll 275 380 10 100 fgcolor: (color 204 153 102)
```

Appendix: D - Experimenting with Random Concept Generation

Smart Phone Builder



Camera Builder



Appendix: E - Main Study: Vase Maker Scripts

1. Manual (Non-random) Vase Maker CAD Tool:

-- Clear old roll-outs

```
if ((vaseRoll != undefined) and (vaseRoll.isdisplayed)) do
	(destroyDialog vaseRoll)
```

-- UI for Vase Builder

```
rollout vaseRoll "Tool 1"
	(
		local up = @"C:\Users\Home\Dropbox\Work\Research\MaxScripts 2014\test\up.bmp"
		local down = @"C:\Users\Home\Dropbox\Work\Research\MaxScripts 2014\test\down.bmp"
		local thin = @"C:\Users\Home\Dropbox\Work\Research\MaxScripts 2014\test\thin.bmp"
		local wide = @"C:\Users\Home\Dropbox\Work\Research\MaxScripts 2014\test\wide.bmp"
		local dia_plus = @"C:\Users\Home\Dropbox\Work\Research\MaxScripts 2014\test\dia_plus.bmp"
		local dia_minus = @"C:\Users\Home\Dropbox\Work\Research\MaxScripts
2014\test\dia_minus.bmp"

		group "Create"
			(
				button but_buildVase "Start" tooltip: "Create a hollow cylinder to start" width:
120
			)
		group "Apply Effects"
			(
				slider sld_tw "- Twist +" range:[0, 900, 0] enabled: false tooltip: "Add a twisting
effect"
				slider sld_sq "- Squeeze +"  range: [-0.4, 10, 0]  enabled: false tooltip: "Add a
squeeze effect"
				slider sld_st " - Stretch +" range:[-0.5, 0.5, 0] enabled: false tooltip: "Add a
stretch effect"
				slider sld_bn "- Bend +" range:[0, 30, 0] enabled: false tooltip: "Add a bend
effect"
			)
		group "Modify Proportions"
			(
				button up_but ""  width: 31 height: 31 images:#(up, undefined, 1, 1, 1, 1, 1)
enabled:false tooltip: "Increase vase height" across: 3
				button dia_plus_but ""  width: 31 height: 31 images:#(dia_plus, undefined, 1, 1,
1, 1, 1) enabled:false tooltip: "Increase vase diameter"
				button wide_but ""  width: 31 height: 31 images:#(wide, undefined, 1, 1, 1, 1, 1)
enabled:false tooltip: "Increase vase width"
				button down_but ""  width: 31 height: 31 images:#(down, undefined, 1, 1, 1, 1,
1) enabled:false  tooltip: "Reduce vase height" across: 3
				button dia_minus_but ""  width: 31 height: 31 images:#(dia_minus, undefined,
1, 1, 1, 1, 1) enabled:false tooltip: "Reduce vase diameter"
				button thin_but ""  width: 31 height: 31 images:#(thin, undefined, 1, 1, 1, 1, 1)
enabled:false tooltip: "Reduce vase width"
			)
```

-- Define Default Variables:

```
	local z = 0
	local base
	global inner
	global x
	global y
	global sq
	global cu
	global a
	global Amp
```

-- Create a basic tube

```
	on but_buildVase pressed do
		(
			x = 70
			y = 300
			sq = 0
			cu = 0
```

```
a = 0.05
Amp = 10
base = cylinder heightsegs:10 radius:(50) height:200
inner = cylinder heightsegs:10 radius: (45) height:200
boolObj.createBooleanObject base
boolObj.SetOperandB base inner 4 2
clearSelection ()
```

-- Add null modifiers for stack position

```
tw = twist angle: 0 bias: 50
	addModifier base tw
bn = bend angle: 0 direction: x
	addModifier base bn
sqz = squeeze Bulge_Amount:0 Bulge_Curvature:0 Squeeze_Amount: 0
Squeeze_Curvature:0
	addModifier base sqz
pin = Stretch Stretch:0 Amplify: 1
	addModifier base pin

#(but_buildvase).enabled = false
#(
--	but_deletevase,
	thin_but,
	wide_but,
	up_but,
	down_but,
	dia_plus_but,
	dia_minus_but,
	sld_sq,
	sld_st,
	sld_bn,
	sld_tw
	).enabled = true
base.wirecolor = color 255 255 255
)
```

-- Modify Vase

```
on sld_sq changed val do
	(
		for base in objects do for m1 = base.modifiers.count to 1 by -1  where classof
base.modifiers[m1] == squeeze do deleteModifier base m1

			(
				sqz = squeeze Bulge_Amount:((sld_sq .value))
Bulge_Curvature:((sld_sq .value)/3) Squeeze_Amount: (sld_sq .value) Squeeze_Curvature:0.5
				addModifier base sqz before: 1
			)
	)
on sld_st changed val do
	(
		for base in objects do for m2 = base.modifiers.count to 1 by -1  where classof
base.modifiers[m2] == stretch do deleteModifier base m2
		(
		pin = Stretch Stretch:(sld_st .value) Amplify: 10
		addModifier base pin
		)
	)
on sld_tw changed val do
	(
		for base in objects do for m3 = base.modifiers.count to 1 by -1  where classof
base.modifiers[m3] == twist do deleteModifier base m3
		(
		tw = twist angle: (sld_tw .value) bias: 50
		addModifier base tw before: 3
		)
	)
on sld_bn changed val do
	(
		for base in objects do for m4 = base.modifiers.count to 1 by -1  where classof
base.modifiers[m4] == bend do deleteModifier base m4
		(
		bn = bend angle: (sld_bn .value) direction: x
		addModifier base bn before: 2
		)
	)
```

```
on dia_plus_but pressed do
	(
		scale base [1.05, 1.05, 1]
	)
on dia_plus_but staypressed do
	(
		scale base [1.05, 1.05, 1]
	)
on dia_minus_but pressed do
	(
		scale base [0.95, 0.95, 1]
	)
on up_but pressed do
	(
		scale base [1, 1, 1.05]
	)
on down_but pressed do
	(
		scale base [1, 1, 0.95]
	)
on thin_but pressed do
	(
		scale base [0.95, 1, 1]
	)
on wide_but pressed do
	(
		scale base [1.05, 1, 1]
	)
)
createDialog vaseRoll 170 400 10 100 fgcolor: (color 10 70 130)
```

2. Random Vase Maker CAD Tool:

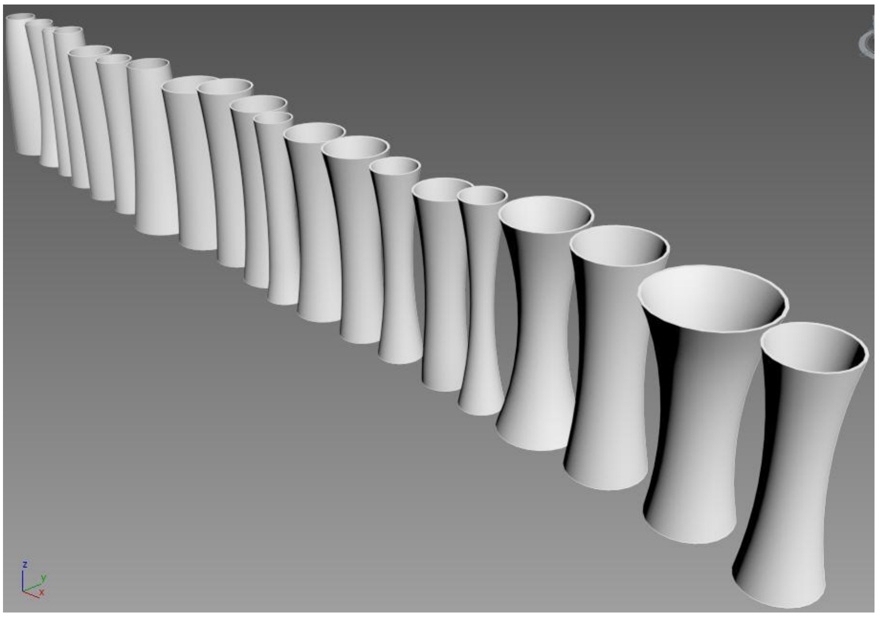
```
-- Clear old roll-outs
if ((vaseRoll != undefined) and (vaseRoll.isdisplayed)) do
	(destroyDialog vaseRoll)

-- UI for Vase Builder
rollout vaseRoll "Tool 2 "
	(
		group "Build"
			(
				button but_add "Add"  width: 120
			)

-- Define Default Variables:
	local z = 0
	local base
	global inner
	global x
	global y
	global sq
	global cu
	global a
	global Amp
	global twa
	global bnd
	global sqz

-- Create a random vase
on but_add pressed do
		(
			x1 = random 50 100
			y1 = random 200 400
			base = cylinder heightsegs:10 radius:x1 height:y1
			inner = cylinder heightsegs:10 radius: (x1-6) height:y1
			boolObj.createBooleanObject base
			boolObj.SetOperandB base inner 4 2
			clearSelection ()
			base.wirecolor = color 255 255 255
			(
				twa = random 0 900
				bs = random 0 50
				tw = twist angle: twa bias: bs
				addModifier base tw
			)
			(
				bnd = random 0 30
				bn = bend angle: bnd
				addModifier base bn
			)
			(
				a1 = random -0.5 0.5
				Amp = random 1 10
				pin = Stretch Stretch:a1 Amplify:Amp
				addModifier base pin
			)
			(
				sq = random -0.1 0.5
				sq1 = random -0.5 0.5
				cu = random -10 10
				cu1 = random 0 0.5
				sqz = Squeeze Bulge_Amount:sq Bulge_Curvature:cu Squeeze_Amount: sq1
Squeeze_Curvature:cu1
				addModifier base sqz
			)
			(
				x = random 0.5 1.25
				y = random 0.5 1.25
				z = random 0.5 1.25
				scale base [x, y, z]
			)
		)
	)
createDialog vaseRoll 150 60 10 100 fgcolor: (color 204 153 102)
```

Appendix: F - A selection of commercially available vases

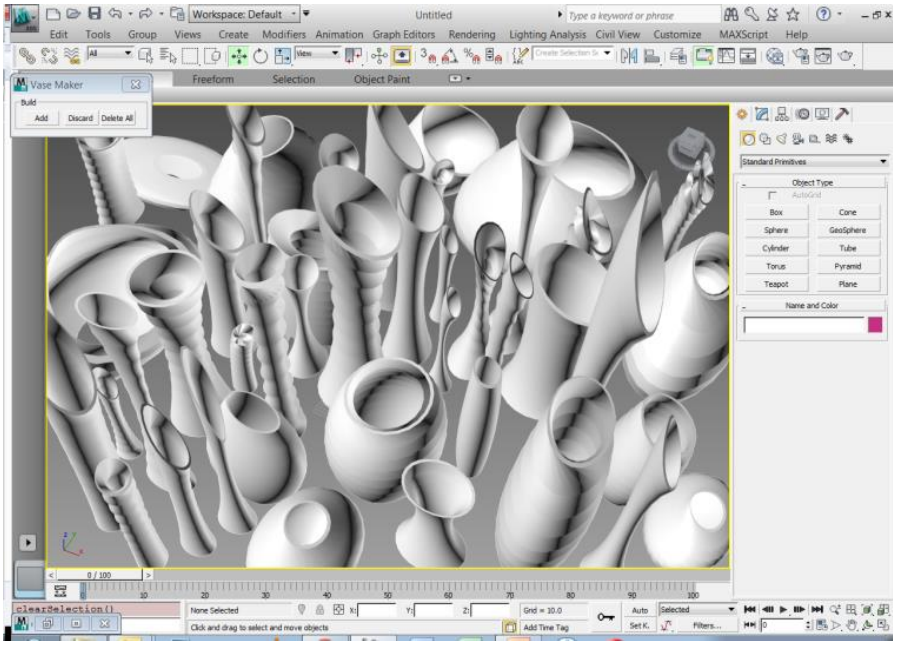
Demonstrating typicality of the vase concepts produced using the CAD tools

Appendix: G - Random Vase Maker CAD Tool - Example Concepts

Early Experimentation Results:



Example results from Final Random CAD Tool:



Appendix: H - Experimental Study - Questions

Product Affect Study

Instructions - Part 1 of 2

The following 9 questions will ask you to indicate your emotional response to a particular design of table. Please take a moment to consider the table-leg and table-top proportions, then select the appropriate button to indicate your emotional response before moving on to the next question.

1. Please indicate your emotional response to the table top/leg proportions:*

Very negative	Negative	Neutral	Positive	Very Positive
○	○	○	○	○

2. Please indicate your emotional response to the table top/leg proportions:*

Very negative	Negative	Neutral	Positive	Very Positive
○	○	○	○	○

3. Please indicate your emotional response to the table top/leg proportions: *

Very negative	Negative	Neutral	Positive	Very Positive
○	○	○	○	○

4. Please indicate your emotional response to the table top/leg proportions: *

Very negative	Negative	Neutral	Positive	Very Positive
○	○	○	○	○

5. Please indicate your emotional response to the table top/leg proportions: *

Very negative	Negative	Neutral	Positive	Very Positive
○	○	○	○	○

6. Please indicate your emotional response: *

Very negative ○ Negative ○ Neutral ○ Positive ○ Very Positive ○

7. Please indicate your emotional response to the table top/leg proportions: *

Very negative ○ Negative ○ Neutral ○ Positive ○ Very Positive ○

8. Please indicate your emotional response to the table top/leg proportions: *

Very negative ○ Negative ○ Neutral ○ Positive ○ Very Positive ○

9. Please indicate your emotional response to the table top/leg proportions: *

Very negative	Negative	Neutral	Positive	Very Positive
○	○	○	○	○

Instructions - Part 2 of 2

The remaining 9 questions will each ask you to compare 3 of the tables. Please use the appropriate buttons to indicate the design you like most and the one you like least.

10. Please indicate which of the 3 tables you like most: *

○ 1 ○ 2 ○ 3

11. Please indicate which of the 3 tables you like least: *

○ 1 ○ 2 ○ 3

12. Please indicate which of the 3 tables you like most: *

○ 1 ○ 2 ○ 3

13. Please indicate which of the 3 tables you like least: *

○ 1 ○ 2 ○ 3

14. Please indicate which of the 3 tables you like most: *

○ 1 ○ 2 ○ 3

15. Please indicate which of the 3 tables you like least: *

○ 1 ○ 2 ○ 3

16. Please indicate which of the 3 tables you like most: *

○ 1 ○ 2 ○ 3

17. Please indicate which of the 3 tables you like least: *

○ 1 ○ 2 ○ 3

18. Please indicate which of the 3 tables you like most: *

○ 1 ○ 2 ○ 3

19. Please indicate which of the 3 tables you like least: *

○ 1 ○ 2 ○ 3

20. Please indicate which of the 3 tables you like most: *

○ 1 ○ 2 ○ 3

21. Please indicate which of the 3 tables you like least: *

○ 1 ○ 2 ○ 3

22. Please indicate which of the 3 tables you like most: *

○ 1 ○ 2 ○ 3

23. Please indicate which of the 3 tables you like least: *

○ 1 ○ 2 ○ 3

24. Please indicate which of the 3 tables you like most: *

○ 1 ○ 2 ○ 3

25. Please indicate which of the 3 tables you like least: *

○ 1 ○ 2 ○ 3

Thank You!

Thank you for taking part in this study. Your response is very much appreciated.

Appendix: I - Designer Participant Questionnaire (Main study)

1. What was your overall impression of interacting with the CAD tool? *(Tick one)*

Very Bad	*Bad*	*Neutral*	*Good*	*Very Good*
☐1	☐2	☐3	☐4	☐5

2. Please indicate what you *like or dislike* about interacting with the CAD tool *(Tick all that apply)*

Like	*Dislike*	
☐	☐	a. Control interface, why?____________________
☐	☐	b. Feedback, why?____________________
☐	☐	c. Speed, why?____________________
☐	☐	d. Other:______________, why?______________

<u>Output:</u> *The final result generated by the first design tool*

3. Please indicate to what extent you liked the concept you created:

Dislike a lot	*Dislike*	*Neutral*	*Like*	*Like a Lot*
☐1	☐2	☐3	☐4	☐5

4. Please indicate to what extent you consider your concept to be original:

Very Unoriginal	*Unoriginal*	*Neutral*	*Original*	*Very Original*
☐1	☐2	☐3	☐4	☐5

5. Please indicate to what extent you consider your concept to be surprising:

No Surprise	*Little Surprise*	*Significant Surprise*	*Highly Surprising*
☐1	☐2	☐3	☐4

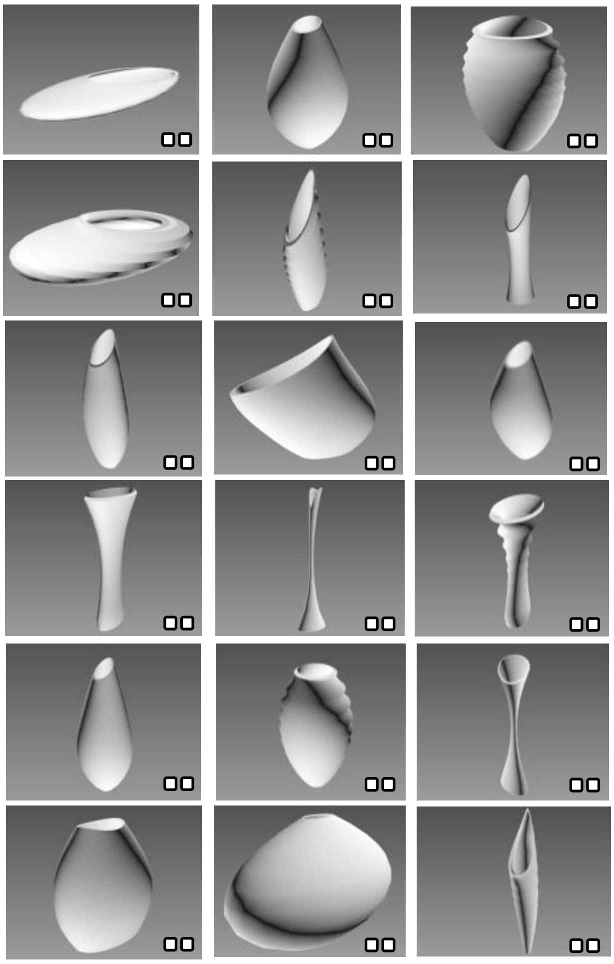
6. Please indicate to what extent you consider your concept to elicit an emotional response:

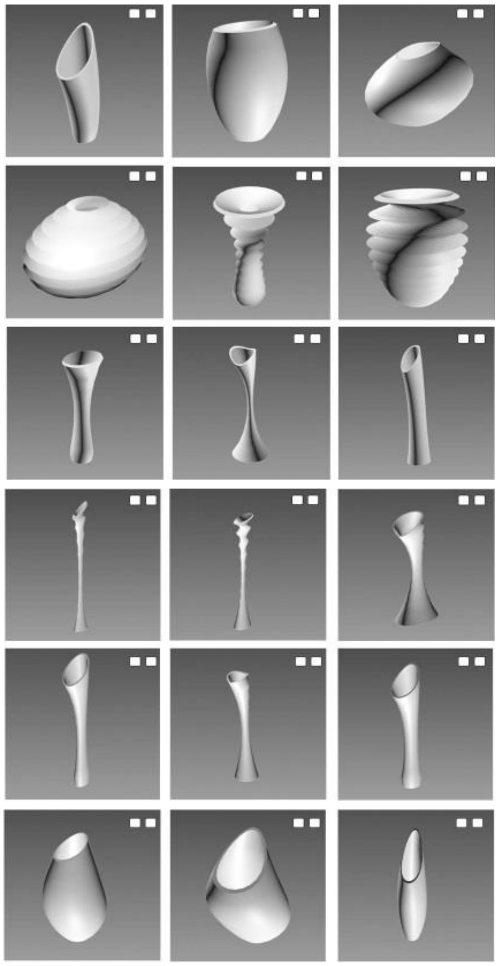
No Emotion	*Little Emotion*	*Significant Emotion*	*High Emotion*
☐1	☐2	☐3	☐4

7. Any other comments:

Appendix: J - Full matrices of concepts created during the Main study

Left: Concepts created by group A1 Right: Concepts created by group A2





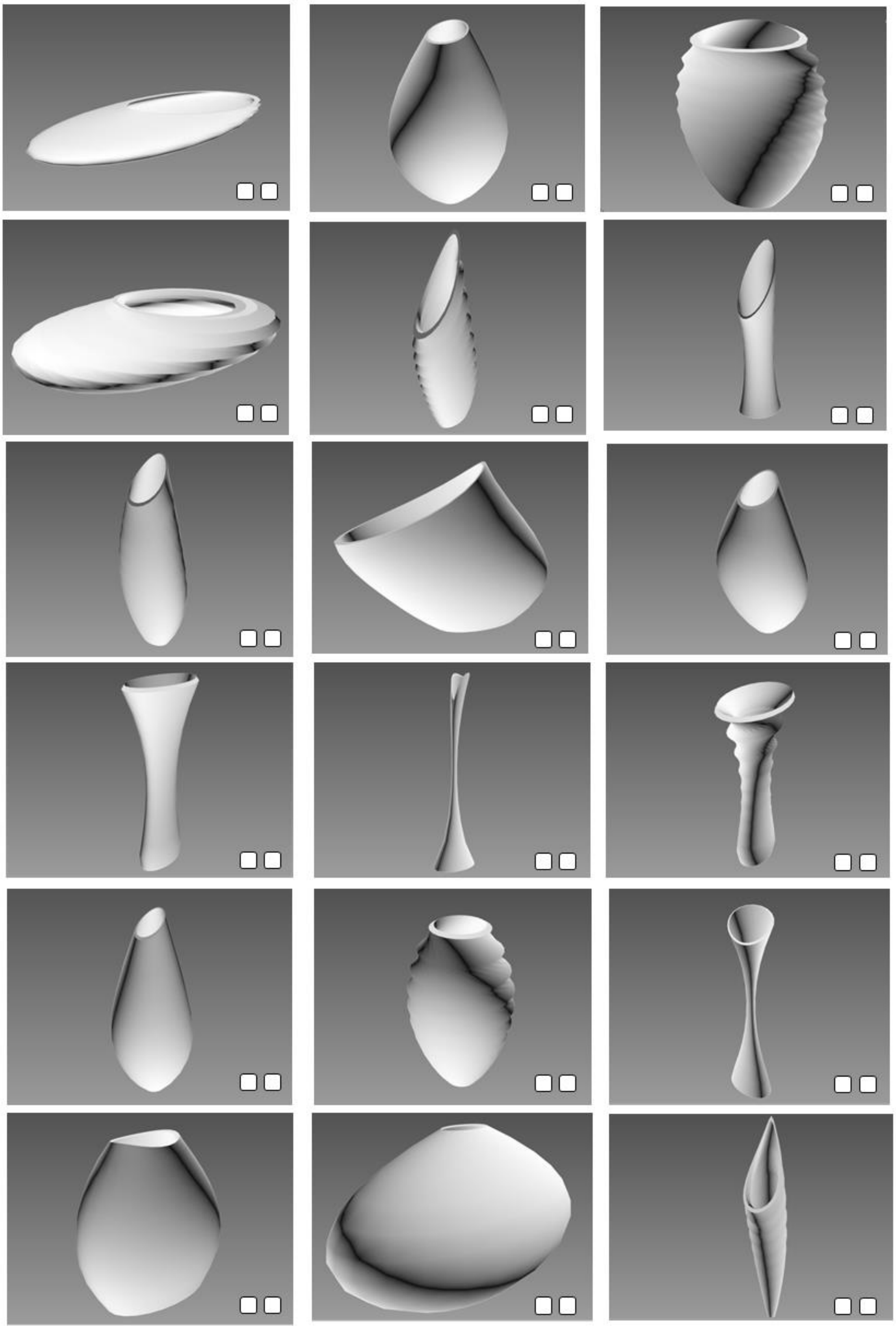
Key to matrix of concepts		
p9v2a	p8v2a	p4v1a
p6v2a	p5v2a	p4v2a
p3v2a	p2v2a	p1v2a
p1v1a	p2v1a	p3v1a
p7v2a	p5v1a	p6v1a
p9v1a	p8v1a	p7v1a

Key to matrix of concepts		
p5v1b	p1v1b	p4v1b
p6v1b	p8v1b	p3v1b
p9v1b	p2v1b	p7v1b
p2v2b	p9v2b	p8v2b
p7v2b	p1v2b	p6v2b
p4v2b	p3v2b	p5v2b

Appendix: K - Main study Questionnaires

<u>Primary Phase - Part 2</u>

<u>For the following vase concepts, please indicate using the boxes provided:</u>
'**1**' The concept you like <u>most</u> and '**2**' The concept you like <u>least</u>,
'**A**' The concept that elicits the <u>strongest emotional response</u> and '**B**' the concept that elicits the <u>weakest emotional response</u>.

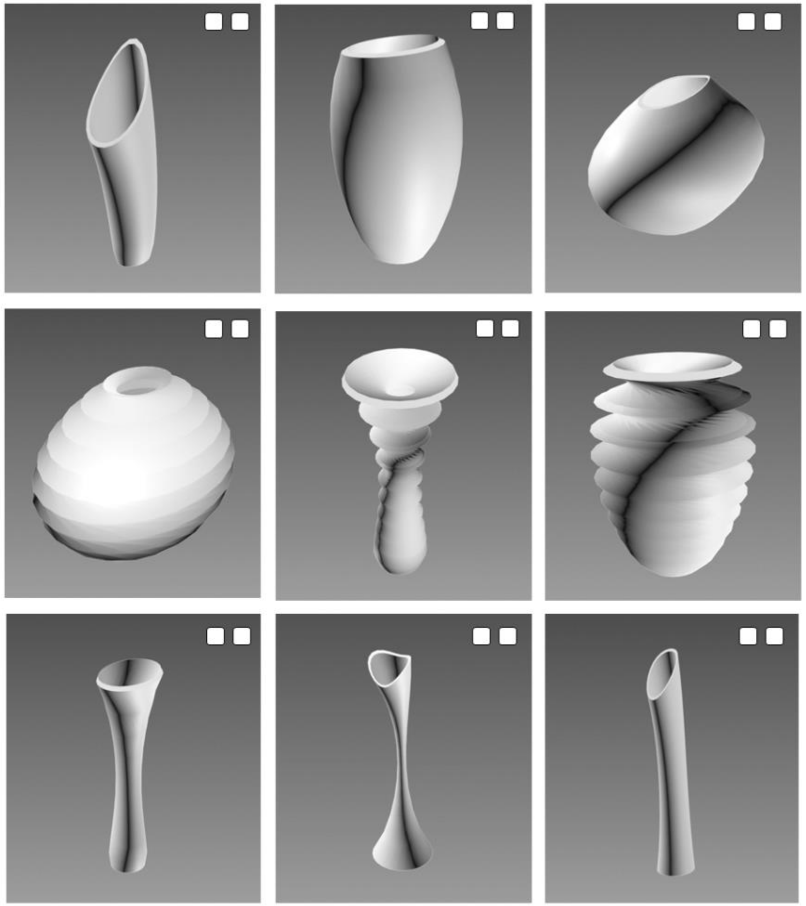


Please tick:
Male ☐ Female ☐ Age: 21-30 ☐ 31-40 ☐ 41-50 ☐ 51-60 ☐ 61+ ☐

Main study Questionnaires: Verification Phase - Part 2

Please Complete All 3 Parts on Both Sides.

1. For the following vase concepts, please indicate using the boxes provided:
'**1**' The concept you like most,
'**2**' The concept you like least,
'**A**' The concept that elicits the strongest emotional response ,
'**B**' the concept that elicits the weakest emotional response.

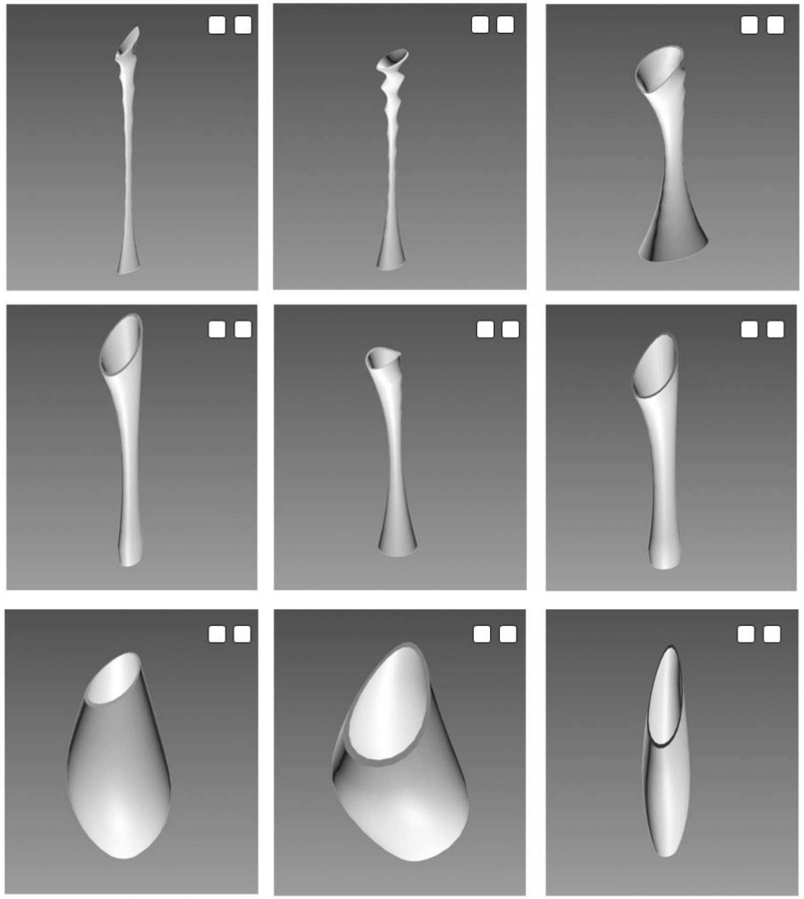


Please tick:

Male Female Age: 21-30 31-40 41-50 51-60 61+

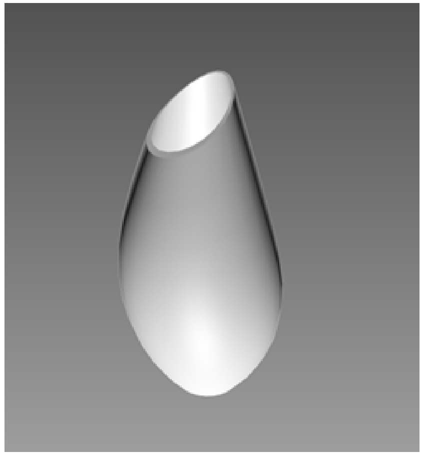
(Page 2.)

2. For the following vase concepts, please indicate using the boxes provided:
'**1**' The concept you like most,
'**2**' The concept you like least,
'**A**' The concept that elicits the strongest emotional response ,
'**B**' the concept that elicits the weakest emotional response.



3. Please put a **tick** and a **cross** against the concepts you like most and least, overall.
Finally, write **Hi** and **Lo** against the concepts eliciting the **highest** and **lowest** emotional response, overall.
THANKS!

Main study Questionnaires: Verification Phase - Part 3



☐ *I like this vase the most*

☐ *This vase elicits the strongest emotional response*

Please indicate *(circle)* the nature of the response

2	1	0	1	2
Unpleasant Surprise		Neither		Pleasant Surprise
Disgust		Neither		Desire
Boredom		Neither		Stimulation

I am:

☐ Male

☐ Female

☐ *I like this vase the most*

☐ *This vase elicits the strongest emotional response*

Please indicate *(circle)* the nature of the response

2	1	0	1	2
Unpleasant Surprise		Neither		Pleasant Surprise
Disgust		Neither		Desire
Boredom		Neither		Stimulation

Appendix: L – Pilot Study Thematic Analysis

Pilot Study – Results and Identification of Themes by Product (1-6)

1 - Water Bottle
Uncertainty about the product resulted in difficulty in expressing a coherent first impression. The packaging was felt to be too different to that of other brands in this sector, "...it's different, but not necessarily in a good way" (25). No emotional response was identified when asked (19).
P2 had seen and used this product before, but she was able to recall her previous experience through reflection. Initial response had been "...wow that's cool" (4). She'd bought and used the product and she appreciates the novelty and intricacy of its design and the underlying meanings it conveys.
P3 had seen the product before (2). She'd bought it (8) and thought it looked like ice (4). She thought it looked cool in both senses of the word (4,10). She thought it looked weird and different (4,12) in a good way.
The participant's first impressions were: refreshing, healthy, transparent, cloudy and smooth (2). It made her feel happy because she likes to drink water (4). She felt slightly drawn to the product but would prefer it to have a blue lid! She would usually choose Evian (16) over any other brand as she likes the taste (18) but would definitely be curious to try this product (26, 28) and would really like to drink it because it's different (30). She liked the perceived simplicity of the design and the emphasis it puts on the contents of the bottle (32).
The participant didn't like the look of the product and didn't appreciate what the designer had tried to achieve. She thought it looked weird (8) and like a deformed (14), melted bottle (4). She didn't think it looked nice (16) and she couldn't identify anything she did like about it.
The participant had no particular feelings to the product (10) and regarded it as plain (14) and ordinary (10). She didn't buy bottled water much which she thought was pointless (20), preferring to drink tap water for free (18).
The participant thought the product looked classy (2). She thought it looked like ice, that it was pleasant and nice (4) and that she would take a closer look at it if she saw it (10). She wasn't one to buy bottled water regularly (6) and thought that if a cheaper bottle was available she would choose that instead (8).
The participant thought the bottle made her think of a stream of water. She thought it had a flow-like quality to it and that the colour of the label and lid also contributed to this effect (2). She described the product as having a calming effect on her. She thought it looked easy to hold and that it was not an aggressive shape (4). She said she tended to buy bottled water on the basis of volume (0.75Litres) (8) and shape (14) rather than brand, price (8) or taste (14). She found the product eye-catching and appealing and thought it made her want to pick it up (14). She noted that it was interesting to have the label at the top rather than around the middle and that the cap was in-keeping with the colours of the bottle (16).

2 - Chair
An immediate response of absolute dislike (31), initially regarding colour (33), then followed by comfort and safety (39). On further investigation it was evident P1 preferred a traditional style to "bright, or weird shapes" (47, 51)
P2 found this product to be too different; more so than was deemed to be necessary or attractive. She liked certain feature details but on the whole felt it was "Weird" (14, 16, 26). She disliked the particular colour, especially for a chair.
P3 thought the product looked strange and uncomfortable (16). She thought it looked more decorative than functional (16). She stated that she did not like the colour (20), but when asked what she liked about the colour she replied that it looked summery and that it might look nice outside (24). She thought the design looked 'cool' but did not like aspects of the back (20).
The participant thought the product looked as if it would hurt her back (36) (she has a back complaint (40)) so she wouldn't choose to sit on it. She thought it was a 'funny' shape and that it wouldn't provide much lower back support (36). She didn't 'trust' it and thought it looked skinny and unstable (36). She also thought is looked like candle-wax and that it might melt (36). She liked the colour (48) thinking it looked like lime and that it looked really bright. She thought she'd definitely notice the chair first if she walked into a room (52).
The participant thought the chair looked weird (20, 36) and out of proportion (20, 38) but not abnormal (22). She thought the design looked deliberate (22) and different (26). She thought she might buy such a chair and use it (22), although she hadn't really thought about what she'd use it for (24) and the colour didn't appeal to her because it wouldn't go with anything (31).
The participant thought the product looked a bit weird, pointless, uncomfortable and like the back was disproportionately small (26). She said it looked like it was just for show (30, 32) and that it wasn't intended to be sat on much (32). She thought the shape was weird (42) and the colour was unusual (46).
The participant thought the colour was horrible but that the design looked modern and funky (16). She thought the colour and the rounded edges gave the product a retro feel (18), perhaps circa 1960's (20). She didn't think it looked particularly comfortable (22, 24) but she thought it looked nice overall (24). She thought it looked simplistic and modern (26). She thought it was a happy piece of furniture and that if she saw it in a shop it might make her smile (32). However, she would not choose to have it in her environment as she prefers wood to plastic (34). She would prefer the product if it had a natural wood finish (40). She disliked the colour as it reminded her of "bogies" (42). She accepted that it was a fun and "summery" colour but that she didn't think she'd be able to have it in a room where she'd be looking at it all the time (44).
The participant was reminded of being young and in playgroup (18). She also said it reminded her of being care-free and that it was more sculptural and rebellious than just a standard chair (20). She liked the chair and thought the colour was bright and spring-like. However, while she thought it looked fun, she also thought it looked uncomfortable. She couldn't perceive the size of the chair but said it reminded her of children and described how if she had children she might like to buy it for them (18). She said the cut-outs in the back reminded her of Easter as they were slightly egg-shaped. She liked the chair but thought it might be awkward to move around or stack (20).

3 - Pocket Knife
No personal context for this product or its use (59, 73) and P1 did not feel strongly about the product (75). First impressions concerned size and colour. P1 would not want to own the product (65) and saw it as more of a gender stereotype product (69).
First impressions-colour, after deliberation. Little personal experience or personal need for this type of product meant that she felt very little towards it. P2 felt it suited the gender stereotype user based on its colour and features (42).
The participant's first response was "wow" (26). She thought it looked dangerous (28) and scary (30), fearing for the personal safety of the person using the knife (34). She perceived the knife to be larger than those used in the kitchen (42) and quite complicated (44) from the image provided.
The participant associated the product with the Army because of the colour (56). She had and foresaw herself having no need for this particular type of knife (58). She thought it looked handy, small and compact, safe to hold, smooth and clean-cut (60). The liked the texture on the handle (60).
The participant thought the product looked sophisticated (40) and technical (50) and like something the Army might use (40). She didn't have any feelings towards the product (44) and had no cause to use such a product (46).
The participant's first impressions were "…looks scary, looks dangerous.". She couldn't see the point of it (54) or why anyone would want one (48) and wouldn't know what to do with it if she had it (60). She thought it looked scary and sharp (50) like a weapon (58). She feared that if she were to use such a knife something bad would happen (54).
The participant's initial reaction was "Eek" (46) a reaction she commonly gets to knives (48). She thought it looked "Army-like" (48) and she stated that she had no interest in weapons or the like (50). She thought she might own a Swiss-army knife but that she hadn't seen it for a very long time (54). She thought the design was nice (56) but masculine (58). She regarded her reaction to the product as being linked to her pacifist views on war and conflict and not her personal safety (62). Otherwise, she was unable to explain her reaction other than it being a natural reaction to something that might be intended to cause harm (64). She hadn't imagined the product being used by or against her personally, but she regarded it as aggressive, scary and more army-like than a normal pocket-knife (66). She thought it looked intimidating (70).
The participant was initially drawn to the colour (26) which suggested the military, and that it immediately made her think of being out in a war. She thought it looked aggressive, cold and metallic with no nice flowing curves. She thought it looked like a weapon that could do damage (22). She (mistakenly) thought it looked like the blades were double edged (26) and that as a result the product looked slightly frightening (28). She thought the product looked compact but dangerous. She could see the product being used to do damage but not necessarily towards her (32). She was comfortable around sharp kitchen knives (she worked in a restaurant) (40) but drew a clear distinction between the two different types (42).

4 - Netbook
The initial reaction was to the colour, but apparently more as a statement of gender stereotype rather than her own personal preference (79, 81). The texture and the branding were disliked (83, 85, and 87). The aesthetics were regarded to be of far less importance than the technical specification (93, 95). P1 remarked that the image shown only conveyed certain aspects of the exterior and that it was hard to draw a clear first impression from it (101).
P2 was interested by the design but disliked the colour (pink); "a definite no-no" (44). She wanted a product of this type to look "cool" (44) and would choose silver over a coloured laptop (46, 48). She did like the ripple texture on the product's surface because it looked "different" (46). She would choose a laptop over a netbook based on size (54) but was not overly disappointed to learn that the product was a Netbook (60). Technical Specification would be an important factor for her (60).
The participant thought the product looked 'cool' and liked the textured surface (50) and the colour (52). She'd not come across netbooks before but she preferred the idea of a smaller laptop (72) but she also felt that performance was very important (66).
The participant liked the colour (62) and thought the product looked nice because of the pattern on the surface (68) and the way it was presented on the screen (68,72). She thought it looked gender stereotypical for a female user due to the colour. She would normally be attracted to aesthetics first, function/features second. "…if it doesn't look nice then I would definitely not buy it. But that looks nice so I'd be attracted to that and then I'd see what it would do" (86). However, she was put-off to learn it was a netbook rather than a larger notebook (88).
The participant thought the product looked different and would be happy to be given it but would not buy it (58). She didn't like the pattern and evidently was unsure what the pattern was from the picture "…I don't really like the thingies, like, pattern on the top" (60). She described her preference as being for plain and simple things; her own laptop being black (72) and chosen initially on looks (70). She said she was still very fond of her current laptop (78)
The participant liked the colour and thought it looked pretty. She thought she'd be more attracted to this product than a plain one (72). She was drawn to the colour first (74). She was unfamiliar with the brand however and would prefer to get a brand she knew (80). She described the pattern on the product's surface as "weird" and "bobbly" and found it annoying. She owned a laptop for uni work (98) and chose it (with her dad) because it was cheap and it was a Toshiba (94) and it was cheap and it had everything she needed, nothing more. (98). She described it's selection as practical.
The participant was initially drawn to the product's outer case (72) and its colour (76). She liked the idea of a coloured laptop, but was more interested in a computer's functionality than its looks (78). She would choose a coloured one if all things were equal, but she wouldn't choose a pink one (80). She liked the pattern on the outer surface (80) but ultimately specification would be the most important factor, followed by cost (84, 86).
The participant thought the product looked *"girly"* because of the colour and the curved edges. She said the pattern on the outer surface made her want to reach out and touch it to see if *"it's squishy or whether it's just the way it's built"* (46). She went on to describe her own laptop and her reason for choosing the one she did over the alternatives. She'd bought a white Macbook. She liked the sleek, smooth curves (48) and the white colour and preferred this to grey or black (50). She was aware of coloured laptops but she was drawn to the Mac (60).

5 - Shoes
An immediate positive reaction (105). The rationale for being: "It's shoes. I like shoes. It's shopping related. It's something that I'd quite regularly buy." (109) P1 was able to give a detailed appraisal of the product rapidly (107, 113), listing a range of features that she found to be particularly attractive.
An immediate positive reaction (64) and P2 liked the shoes immensely (68). P2 liked the colours and was immediately drawn to the design details. She gave an enthusiastic and detailed appraisal of the product (64, 68) She reflected upon the types of compliments the wearer might receive and the clothes one would wear with them (64).
The participant was familiar with shoes like these but had not seen these before. She felt more comfortable discussing shoes (78). She liked the colour, the heels and the style immediately (84) and was able to discuss the design in detail, reflecting on the attire and usage occasion with which they might be worn (82).
The participant was happy when she saw the shoes. She 'loved' the platform, the heels and the curve of the ankle. She would buy them even though she wouldn't have anything to wear with them (92). She 'loves' shoes and described herself as a 'shoe-addict' (94). She went on to describe the design features that she liked and why she liked them. Her initial thoughts on seeing the shoes had been to do with accompanying attire (skirt, no tights), summer (110) and due to the open toe, nail-varnish (112). She would only wear them for a special occasion such as socialising, dancing or going to a wedding (104, 108, 112). She also thought it was a youthful design (118) and that they'd probably only appeal to customers in their late teens up to those in their middle ages (116). She thought they looked young and fresh and that one would wear them to have a good time (118).
The participant thought the shoes looked nice (80) and expensive (84) and that she'd be happy to wear them but that she wouldn't buy them (80). She didn't think they were her style or that they'd go with much when wearing all one colour (82). She thought they looked of a high quality (88) due to the detail and the amount of effort that appeared to have been put into them (92).
The participant immediately thought the shoes looked ugly and overtly sexual, like those a prostitute would wear (104, 108, 110). She thought they looked dated, too tall, and she didn't like the black and white together (110). She agreed that she'd had a strong reaction to them and she thought she'd probably laugh at anyone she saw wearing them (114). She thought they were for people that liked to show-off (116).
The participant's first impression had been "…wow, that's a pair of shoes!" (92) and she'd had an image of a wealthy, classy woman, possibly wearing the shoes with a suit (94). She thought the shoes looked nice and expensive but uncomfortable (88). She thought they looked expensive because of the attention to detail (90) and she highlighted certain details by way of example. She didn't associate her perceived user as being any way near to her own culture. She thought they were impractical and high-fashion. She imagined her mother saying so. She thought there was a complete contrast between their beauty and the agony she perceived the wearer would endure whilst wearing them. She thought the shoes reminded her of Japanese Geisha and associated this with the degree of control that would be required to wear them (96).
The participant's first response was "I wouldn't be able to walk in those" (68). She thought they looked masculine and went on the explain her rationale as being based on the aggressive design (70) and the contrasting colour and associated these traits with the design of men's shoes (74). She thought that anyone wearing them would want to make a statement through doing so (70, 76). She thought they were bold and different and not something she'd choose personally (76).

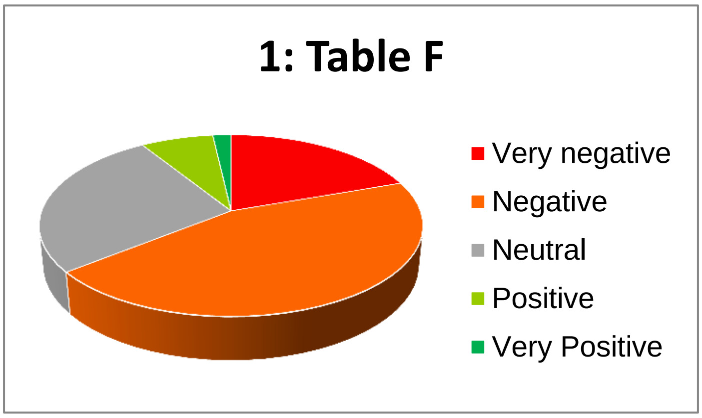
6 - Lint Shaver
P1 could not clearly identify the product's function or purpose (121). This apparently affected her impression of the product which was given in a more hesitant manner (125, 129). Feelings were neutralised while she tried to identify a context/use for the product (131, 133). A mild positive surprise was experienced when the product's purpose was revealed (137).
P2 could not identify the product's function or purpose. She identified with the product's characterisation and was drawn to it, seeing it as "cute" (80) and duck-like in form (74). She was curious and intrigued by it (76, 78). She reacted positively when the product's function was revealed (80), a reaction reinforced by her own personal need for such a product.
The participant could not tell what the product was at first (90). She tried to guess (speaker, toy etc. (94)) and thought it reminded her of a bath-duck (96). She thought it looked small enough to be hand-held (108). She laughed when the product's purpose was revealed (98), but had not use for such a product and so would not buy one (102). She did think it was intriguing enough that if she saw it in a shop she'd go a take another look (104).
The participant did not know what the product was and guessed it might be a webcam (124). She thought it looked tiny and fragile (130) and suspected it might be a hand-held device (142). She thought she'd pay it little attention if she couldn't tell what it was (132). Once revealed, she thought the product function was necessary, but that she wouldn't be drawn to this particular device because of its design and ergonomics (140).
The participant didn't know what the product was (98). She guessed a loudspeaker (98) and thought it resembled a duck (100). She thought it looked quite cool (102) but thought the only way to figure out how to use it would be to play with it, and pull it apart (106). When the purpose was revealed she described it as "…a bit random" (108). She described her surprise as pleasant (118) because she was unaware such products existed. She didn't think she had much use for such a product now but thought that in hindsight she could have done with one when she used to wear jumpers to school (110).
The participant could not tell what the product was (120, 124) but guessed it was probably an electrical device because of the colours and materials (130). She thought it looked weird and alien and that it might have a speakerphone or a radio built-in. She also thought part of it looked like it might be a mini-fridge (124). She thought it looked intriguing and cool (126, 132), but that she wouldn't give it a second look unless she came across it while browsing in a shop (126). She thought the colour made it stand out (128) and that it was a funny shape (134), rather like a bowling pin (138). When the product's purpose was revealed she was surprised (142), but also a little disappointed (144) as she no longer found it as intriguing.
The participant could not tell what the product was but she thought it looked a bit like a penguin, slightly futuristic and possible a loudspeaker (104). She thought it looked hand-held due to its shape (106). She thought she'd got the idea of a penguin from what she perceived as being eyes on the side of the product and that the shape was very simplified and quite bizarre (108). She described her feelings as "confusion" (110) and as being so bombarded with thoughts of "I don't know what this is" that she was unable to describe any other feelings (112). She thought the product looked like it might be child-orientated (112). She found it intriguing and thought that she might give it a second look if she saw it in a shop. But she also thought she'd probably move on if she got bored trying to work out what it was for (114). She admitted that she found not knowing what the product did was frustrating (116) and she was (mildly) pleasantly surprised when the product's purpose was revealed (126). She thought the product was useful (12) but that the design's "novelty" look made it look cheap (132) and that this was perhaps contrary to its designer's intention (128).
The participant could not tell what the product was and thought it looked a bit like a frog. She found it intriguing and thought it made her want to pick it up. She thought that if she saw it in a shop that she'd be drawn to it because it looks different. She thought it looked sleek, fun and bright (78). She was "taken aback" to discover the product's purpose and she thought its function seemed at odds with its style, looking childish, playful (88) and "immature for something like that" (82). She'd expect such a product to be more conservative, but she also seemed to confuse the product with one designed to remove dust from dark clothes (82, 90) rather than bobbles from knitwear. She didn't think she'd have a use for such a product but was still intrigued enough that she wanted to take a closer look (86).

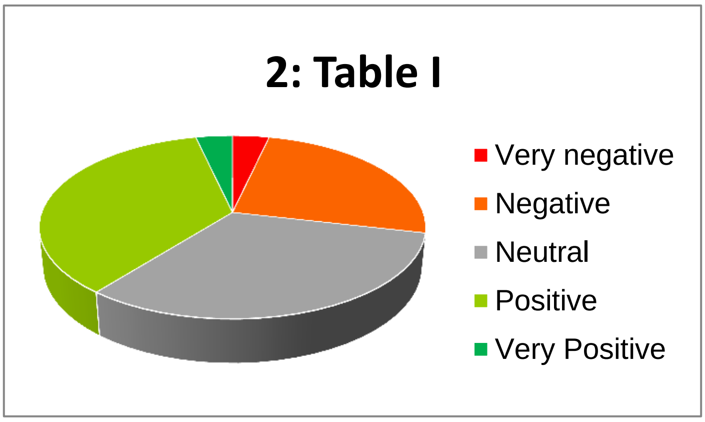
Appendix: M - Exploratory Study: Results

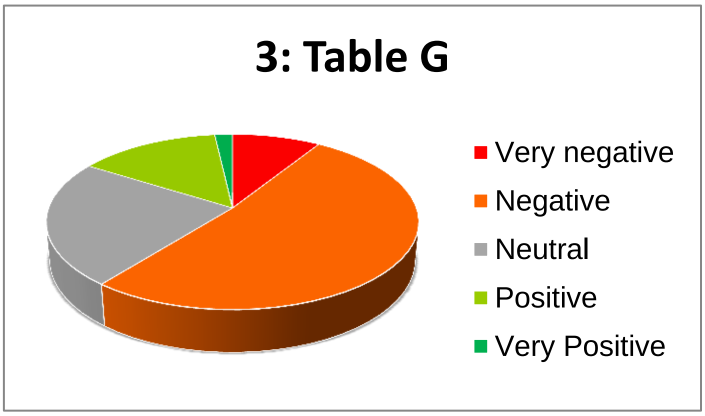
Part one: *(Q1-9) required respondents to indicate their emotional response to each table concept, using a 5-point Likert scale.*

Emotional Responses to Table Concept Proportions shown in Q1 to Q3

‘Please indicate your emotional response to the table top/leg proportions’.

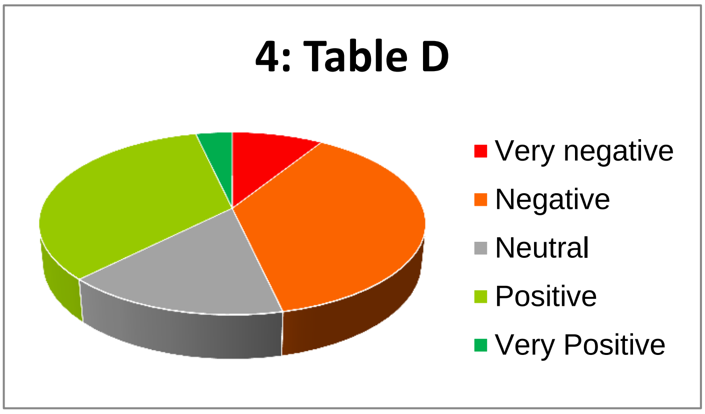


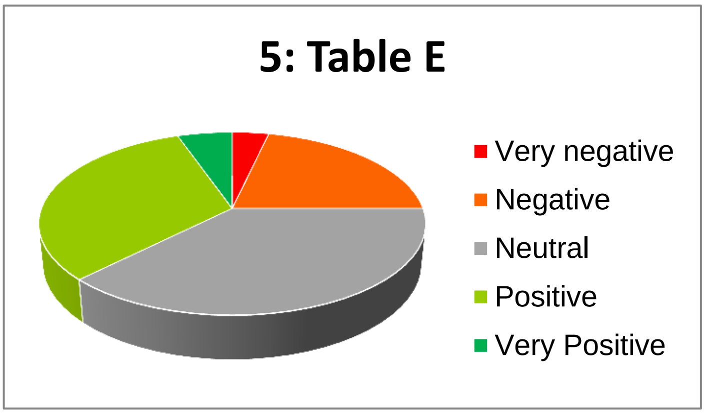


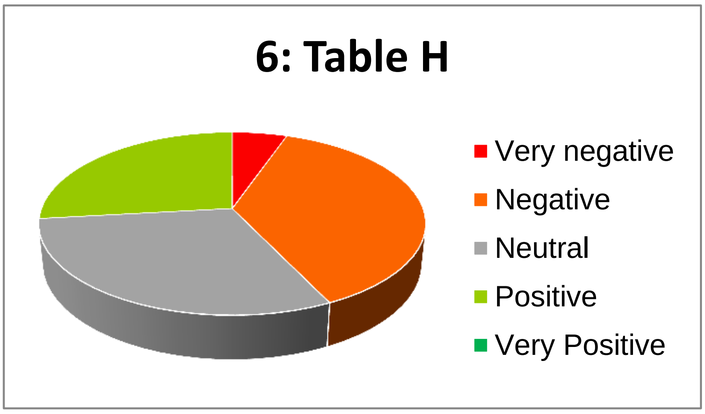


Emotional Responses to Table Concept Proportions shown in Q4 to Q6

‘Please indicate your emotional response to the table top/leg proportions’.

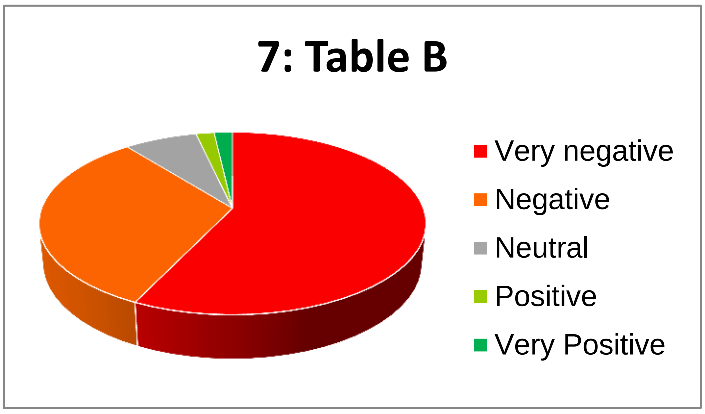


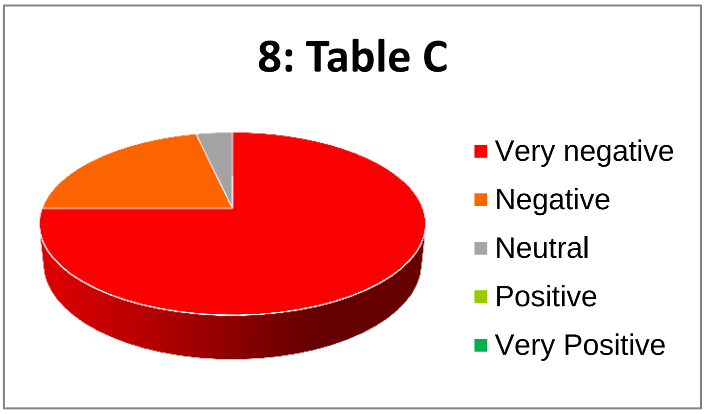


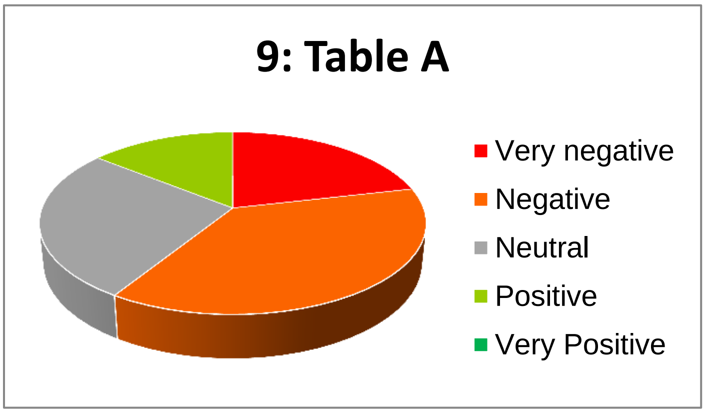


Emotional Responses to Table Concept Proportions shown in Q7 to Q9

'Please indicate your emotional response to the table top/leg proportions'.







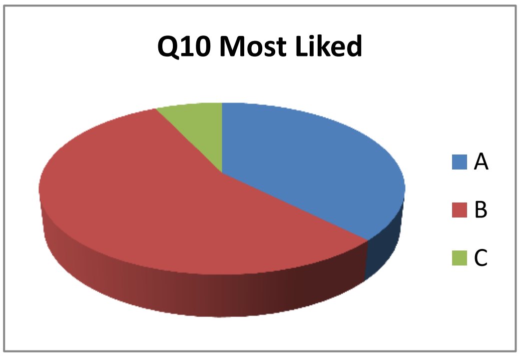
Part two: *(Q10-25) required respondents to indicate the designs they liked most and least from eight combinations of three table concepts.*

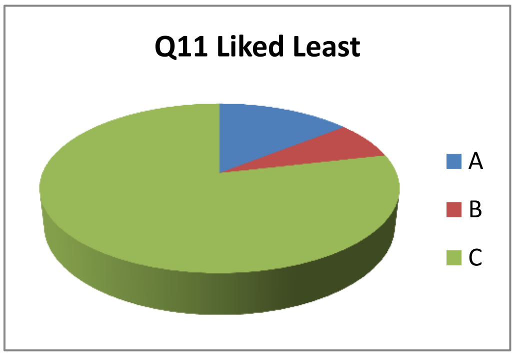
The results of the table comparisons Q10-Q13:

A

B

C

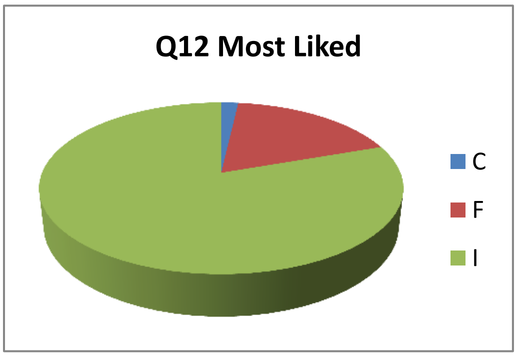


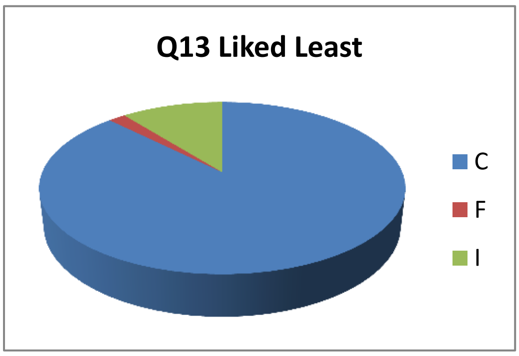


C

F

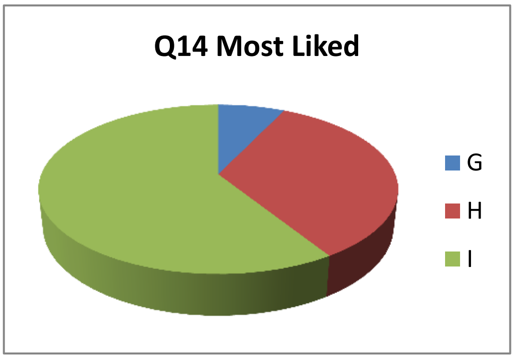
I

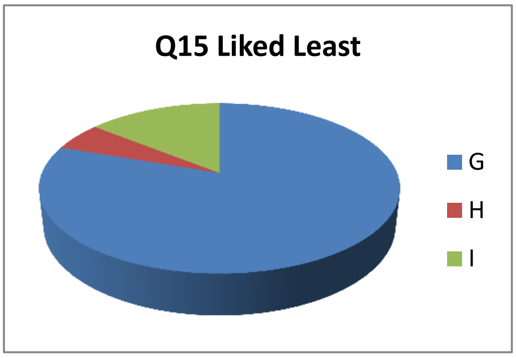




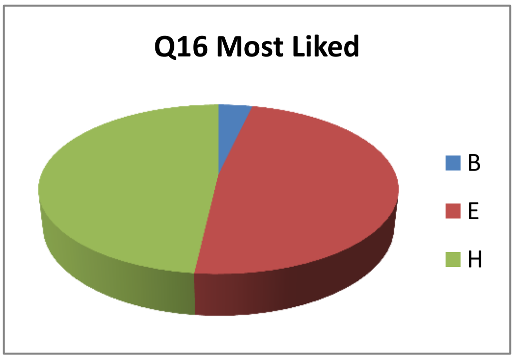
The results of the table comparisons Q14-Q17.

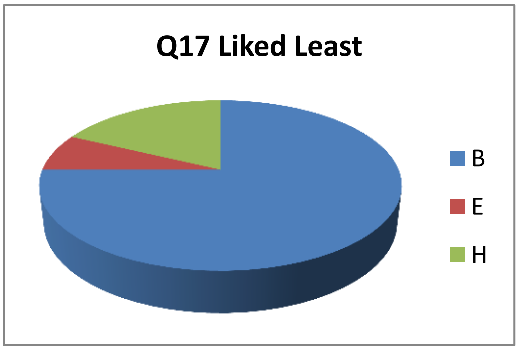
G **H** **I**





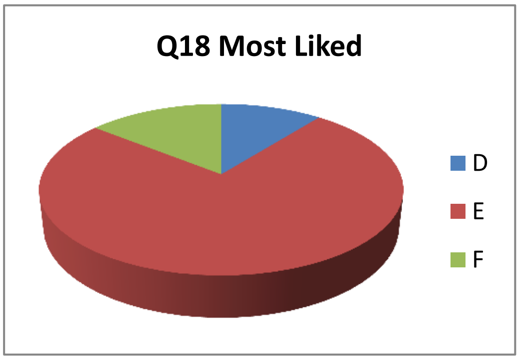
B **E** **H**

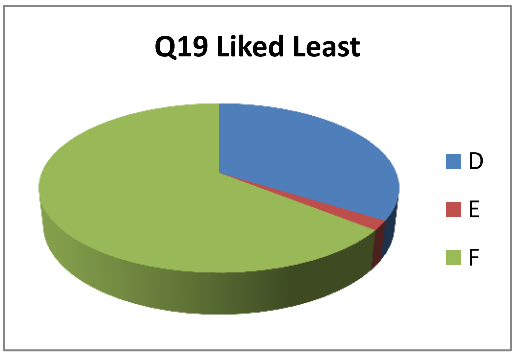




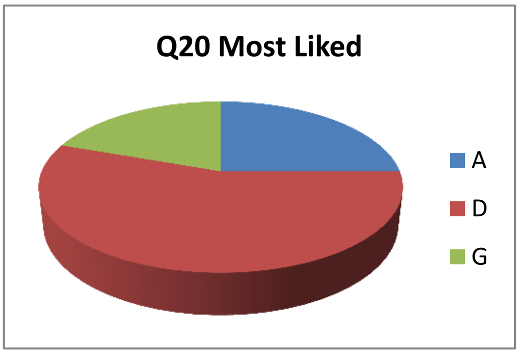
The results of the table comparisons Q18-Q21.

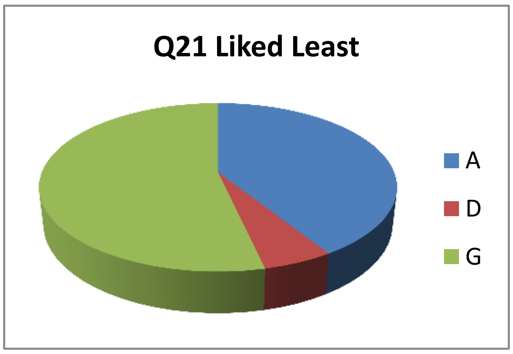
D **E** **F**





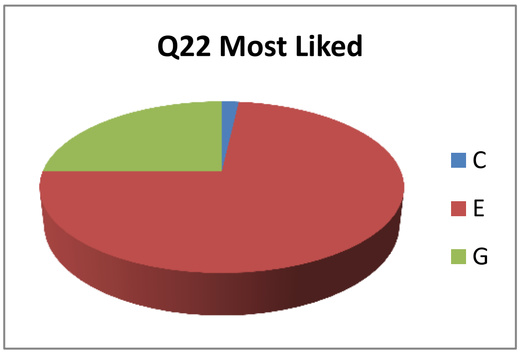
A **D** **G**

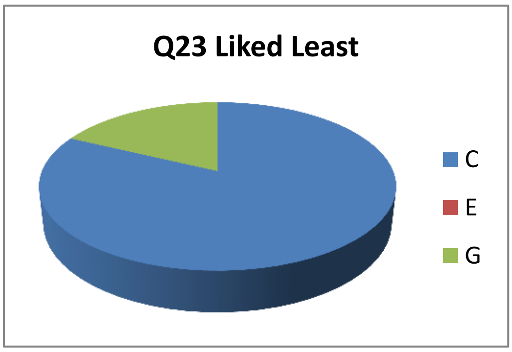




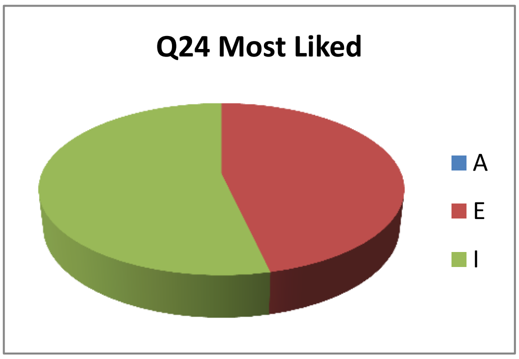
The results of the table comparisons Q22-Q25.

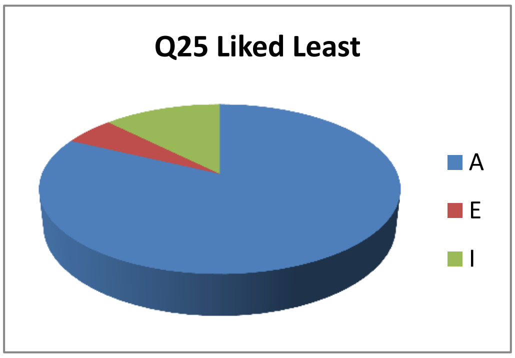
C E G





A E I





Appendix: N - Experimental study: Inter-Rater Reliability Tests

Q1-9:

	1-F	2-I	3-G	4-D	5-E	6-H	7-B	8-C	9-A	Sum	
Very negative	11	2	5	5	2	3	32	42	12	114	**0.226**
Negative	25	14	29	21	12	21	18	12	21	173	**0.343**
Neutral	15	18	13	9	21	17	4	2	15	114	**0.226**
Positive	4	20	8	19	18	15	1	0	8	93	**0.185**
Very Positive	1	2	1	2	3	0	1	0	0	10	**0.020**
	0.303	**0.283**	**0.339**	**0.278**	**0.281**	**0.295**	**0.425**	**0.603**	**0.266**		

Q: Please indicate your emotional response to the table top/leg proportions

	p_bar	**0.341**
	Pe	**0.255**
Fleis' Kappa	K	**<u>0.12</u>**

Q 10-25:

	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Sum	
1	21	8	1	49	4	45	2	42	6	19	14	23	1	46	0	46	178	**0.199**
2	31	4	10	1	19	3	27	4	42	1	31	3	41	0	26	3	141	**0.157**
3	4	44	45	6	33	8	27	10	8	36	11	30	14	10	30	7	185	**0.206**
	0.44	**0.64**	**0.67**	**0.77**	**0.46**	**0.66**	**0.46**	**0.59**	**0.59**	**0.52**	**0.40**	**0.45**	**0.59**	**0.70**	**0.49**	**0.69**		

Q: Please indicate which of the 3 tables you like most/least (1,2,3 = table concepts)

p_bar	**0.57**
Pe	**0.11**
K	**<u>0.52</u>**

Appendix: O - Comparison Breakdown by Emotional Response

In response to concept P2v1a:

76% of participants experienced a pleasant surprise, 23% of which was considered very pleasant.

12% of participants experienced no surprise at all.

12% of participants experienced an unpleasant surprise, 50% of which was considered very unpleasant.

In response to concept P4v2b:

35% of participants experienced a pleasant surprise response, 17% of which was considered very pleasant.

53% of participants experienced no surprise at all.

12% of participants experienced an unpleasant surprise, 0% of which was considered very unpleasant.

In response to concept P2v1a:

65% of participants experienced a desirable response, 36% of which was considered very desirable.

18% of participants experienced no desire or disgust at all.

18% of participants experienced a disgusted response, 0% of which was considered very disgusted.

In response to concept P4v2b:

47% of participants experienced a desirable response, 25% of which was considered very desirable.

41% of participants experienced no desire or disgust at all.

12% of participants experienced a disgusted response, 0% of which was considered very disgusted.

In response to concept P2v1a:

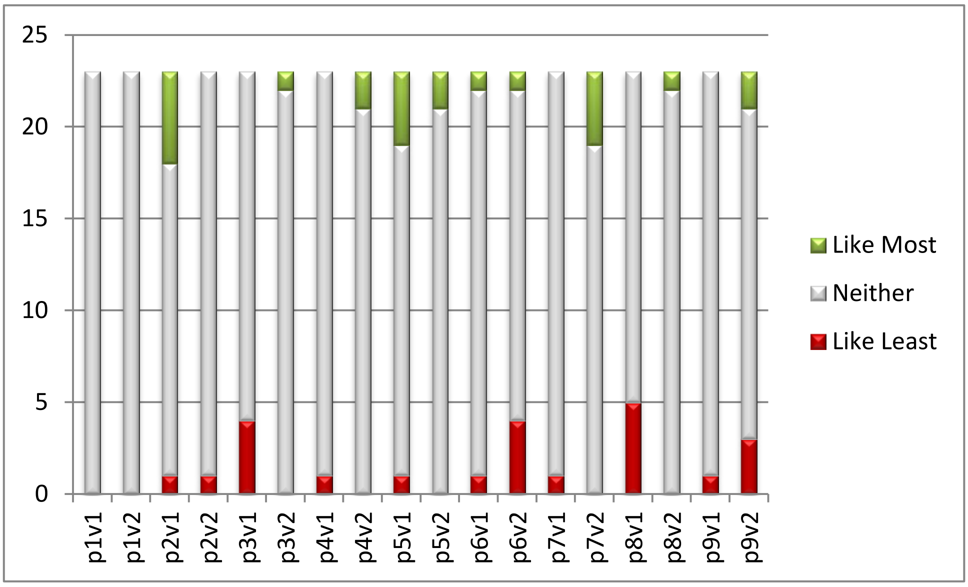
- 82% of participants experienced a stimulated response, 50% of which was considered very stimulated.
- 18% of participants experienced no stimulation or boredom at all.
- 0% of participants experienced a bored response.

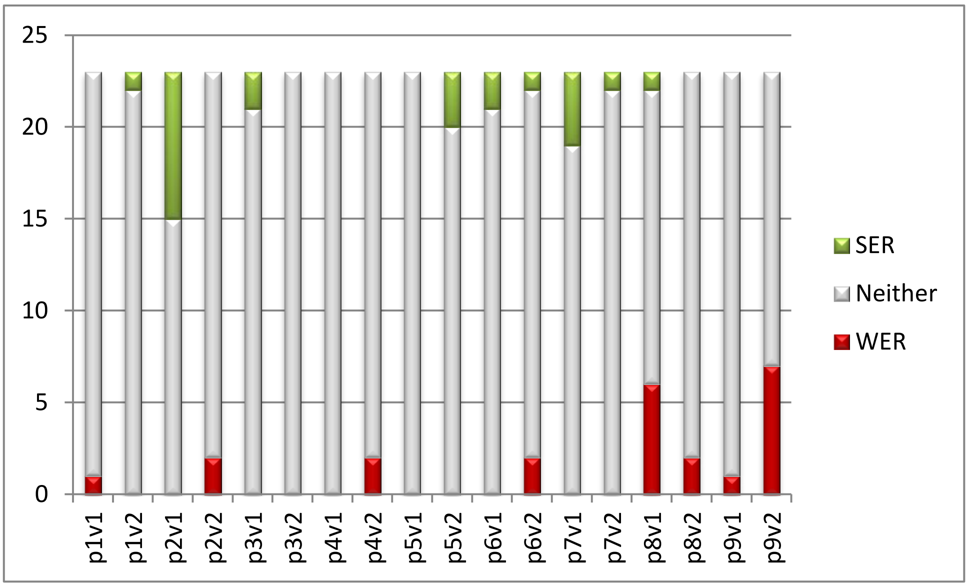
In response to concept P4v2b:

- 35% of participants experienced a stimulated response, 0% of which was considered very stimulated.
- 35% of participants experienced no stimulation or boredom at all.
- 29% of participants experienced a bored response, 20% of which was considered very bored.

Appendix: P - Relative Data Values

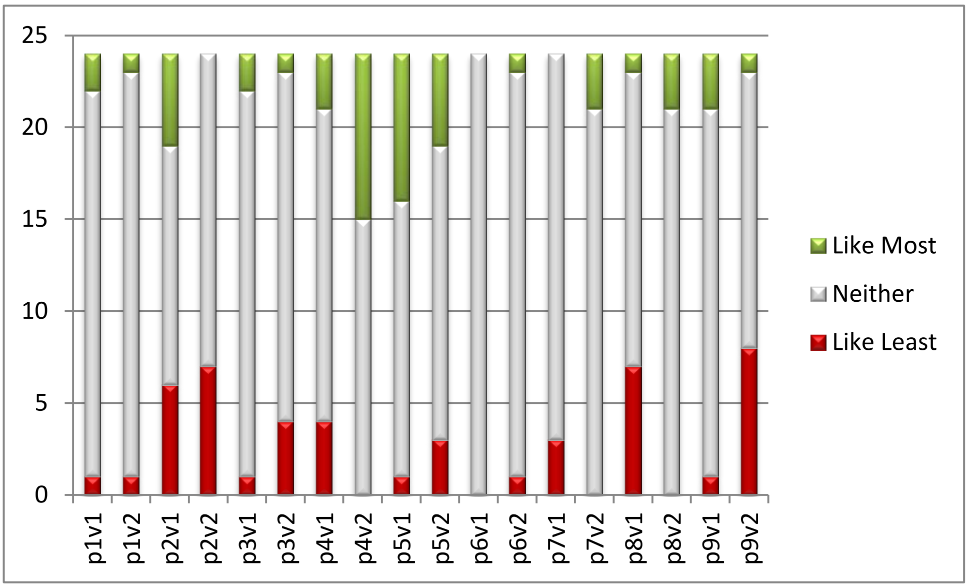
Main Study: Primary Phase Part 2

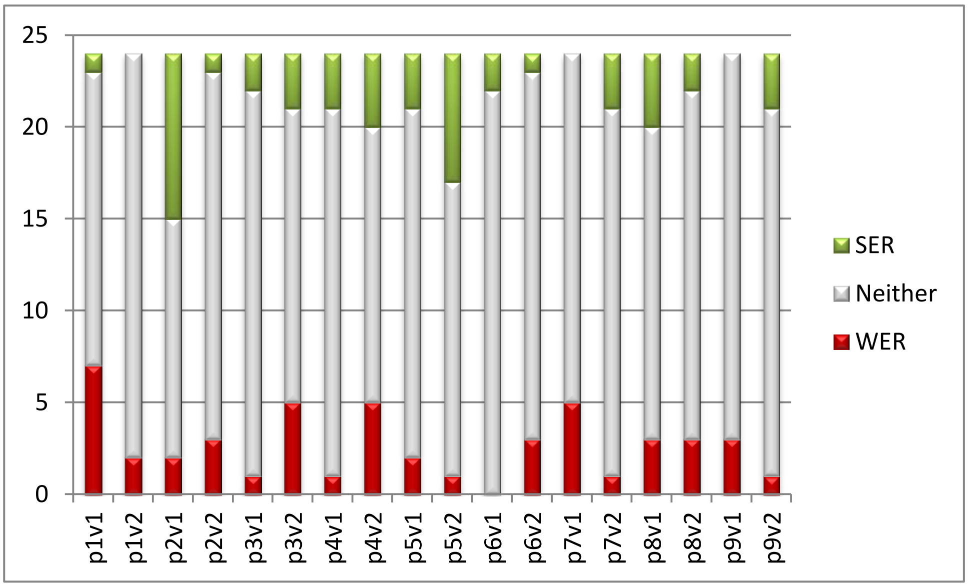




Relative Data Values cont'd

Main Study: Verification Phase Part 2





Appendix: Q - Parametric Analysis of Vase Concepts

- Proportion

The overall mean proportion ((X*Y)/Z value) for all thirty six concepts was 195.8 with a standard deviation of 437.3.

The mean proportion for the most liked concepts was **63.2** with a standard deviation of 50. The corresponding value for the least liked concepts was 351.3 with a standard deviation of 575. This disparity can largely be attributed to a single concept (p6v2a), the removal of which from the calculation brings the average proportion of least liked concepts much closer, to **64.6** with a standard deviation of 59.

The mean proportion ratio of most liked to least liked concepts ≈ 1:1

The mean proportion for the highest SER concepts was **33.1** with a standard deviation of 17. The corresponding value for the WER concepts was 935.8 with a standard deviation of 1644. Again, the disparity can largely be attributed to a single concept (p9v2a), the removal of which from the calculation brings the average proportion of WER concepts somewhat closer, to **113.7** with a standard deviation of 19.

The proportion ratio of SER to WER concepts (33.1: 113.7) ≈ 0.3:1

The proportion ratio of most liked concepts against SER concepts (63.2:33.1) ≈ 2:1 while the corresponding ratio of least liked concepts against WER concepts (351.3:935.8) ≈ 0.4:1 (or for 64.6:113.7 ≈ 0.6:1).

- Twist Angle

The overall mean twist angle for all thirty six concepts was 228.1° with a standard deviation of 245.8.

The mean twist value for the most liked concepts was 13° with a standard deviation of 25. The corresponding value for the least liked concepts was 517.9° with a standard deviation of 378.

The twist-angle ratio for most liked to least liked concepts ≈ 1:40

The mean twist value for the SER concepts was 141.5° with a standard deviation of 234. The corresponding value for the WER concepts was 89° with a standard deviation of 63. The high standard deviation of the SER concepts is due to two of them featuring no twist angle what-so-ever.

The twist-angle ratio for SER to WER concepts ≈ 1.6:1

The twist-angle ratio for SER against liked most concepts ≈ 11:1
The twist-angle ratio for liked least against SER concepts ≈ 3.6:1
The twist-angle ratio for WER against liked most concepts ≈ 6.8:1
The twist-angle ratio for liked least against WER concepts ≈ 5.8:1

- Bend Angle

The overall mean bend angle for all thirty six concepts was 15° with a standard deviation of 11.3.

The mean bend value for the most liked concepts was 18° with a standard deviation of 10. The corresponding value for the least liked concepts was 7° with a standard deviation of 11. Two of the least liked concepts had no bend angle what-so-ever.

The bend ratio for these values (liked most: liked least) ≈ 2.6

The mean bend value for the SER concepts was 26° with a standard deviation of 3. The corresponding value for the WER concepts was 15.1° with a standard deviation of 16.

The bend ratio for these values (SER:WER) ≈ 1.7

The bend-angle ratio for SER against liked most concepts ≈ 1.4:1
The bend-angle ratio for SER against liked least concepts ≈ 3.7:1
The bend-angle ratio for liked most against WER concepts ≈ 1.2:1
The bend-angle ratio for WER against liked least concepts ≈ 2.2:1

- Bulge Amount

The overall mean bulge amount for all thirty six concepts was 0.2 with a standard deviation of 0.2.

The mean bulge amount value for the most liked concepts was 0.19 with a standard deviation of 3.7. The corresponding value for the least liked concepts was 0.10 with a standard deviation of 4.

The bulge amount ratio for these values (liked most: liked least) ≈ 2

The mean bulge amount value for the SER concepts was 0.11 with a standard deviation of 3.3. The corresponding value for the WER concepts was 0.10 with a standard deviation of 5.

The bulge amount ratio for these values (SER:WER) ≈ 1

The bulge amount ratio for liked most against SER concepts ≈ 1.7
The bulge amount ratio for SER against liked least concepts ≈ 1.1
The bulge amount ratio for liked most against WER concepts ≈ 1.9
The bulge amount ratio for WER against liked least concepts ≈ 1.0

- Squeeze Amount

The overall mean squeeze amount for all thirty six concepts was 0.1 with a standard deviation of 0.4.

The mean squeeze amount value for the most liked concepts was -0.12 with a standard deviation of 2.6. The corresponding value for the least liked concepts was 0.19 with a standard deviation of 2.

The squeeze amount ratio for these values (liked most: liked least) ≈ -0.6:1

The mean squeeze amount value for the SER concepts was -0.29 with a standard deviation of 11.5. The corresponding value for the WER concepts was -0.06 with a standard deviation of 3.3.

The squeeze amount ratio for these values (SER:WER) ≈ 4.8:1

The squeeze amount ratio for SER against liked most concepts ≈ 2.4:1
The squeeze amount ratio for SER against liked least concepts ≈ -1.5:1
The squeeze amount ratio for liked most against WER concepts ≈ 2.0:1
The squeeze amount ratio for liked least against WER concepts ≈ -1.5:1

- Stretch

The overall mean stretch value for all thirty six concepts was 0.0 with a standard deviation of 0.3.

The mean stretch value for the most liked concepts was -0.04 with a standard deviation of 2.8. The corresponding value for the least liked concepts was -0.03 with a standard deviation of 2.

The stretch ratio for these values (liked most: liked least) ≈ 1.3:1

The mean stretch value for the SER concepts was 0.14 with a standard deviation of 2.6. This corresponded with a value of -0.3 for the WER concepts, with a standard deviation of 6.

The stretch ratio for these values (SER:WER) ≈ 0.46:-1

The stretch ratio for liked most against SER concepts ≈ -2.6:1
The stretch ratio for SER against liked least concepts ≈ -4.7:1
The stretch ratio for liked most against WER concepts ≈ -1.3:1
The stretch ratio for WER against liked least concepts ≈ -10:1

Appendix: R - Parametric Comparisons

Most liked and least liked concepts of the Main Study.

Main Study

Concept	Size				Twist		Bend	Squeeze		Stretch	
Manual	X	Y	Z	X*Y/Z	Angle	Bias	Angle	Bulge Amount	Sqz Amount	Stretch	Amplify
P1v1	153.0	78.8	291.5	41.4	0.0	50.0	0.0	0.29	0.59	0.11	10.0
P2v1	38.5	56.3	241.6	9.0	0.0	50.0	23.1	-0.20	-0.40	0.43	10.0
P3v1	166.9	255.4	532.7	80.0	528.5	50.0	0.0	0.35	0.71	0.11	10.0
P4v1	265.4	182.5	299.1	162.0	330.0	50.0	8.5	0.17	0.33	-0.08	10.0
P5v1	93.9	100.3	155.2	60.7	388.1	50.0	0.0	0.22	0.44	-0.11	10.0
P6v1	71.7	97.7	373.2	18.8	0.0	50.0	10.7	0.12	0.23	0.50	10.0
P7v1	71.7	97.7	373.2	18.8	355.1	50.0	30.0	0.47	0.94	-0.16	10.0
P8v1	77.3	131.1	80.1	126.6	0.0	50.0	0.0	-0.10	-0.19	-0.35	10.0
P9v1	182.4	93.1	180.3	94.2	99.1	50.0	14.6	-0.14	-0.28	-0.08	10.0

High rank

Concept	Size				Twist		Bend	Squeeze		Stretch	
Random	X	Y	Z	X*Y/Z	Angle	Bias	Angle	Bulge Amount	Sqz Amount	Stretch	Amplify
P1v2	130.9	155.1	273.6	74.2	149.0	7.0	14.0	0.23	-0.46	-0.24	10.0
P2v2	315.7	131.0	240.1	172.3	37.0	5.0	30.0	0.15	-0.26	-0.10	10.0
P3v2	102.3	136.4	336.3	41.5	224.0	39.0	13.0	0.31	-0.39	-0.17	7.0
P4v2	153.4	129.9	545.2	36.5	227.0	19.0	22.0	0.38	0.43	0.06	8.0
P5v2	171.8	78.6	372.5	36.2	489.0	24.0	25.0	0.43	-0.24	-0.17	4.0
P6v2	406.2	365.1	122.4	1211.5	479.0	35.0	24.0	-0.08	0.20	-0.28	7.0
P7v2	205.2	180.9	444.5	83.5	51.0	45.0	8.0	0.40	-0.32	-0.42	6.0
P8v2	312.4	249.8	400.2	195.0	57.0	45.0	7.0	0.19	-0.18	-0.37	6.0
P9v2	839.6	409.6	101.1	3401.9	142.0	40.0	30.0	-0.04	-0.17	-0.42	8.0

Verification Study

Concept	Size				Twist		Bend	Squeeze		Stretch	
Manual	X	Y	Z	X*Y/Z	Angle	Bias	Angle	Bulge Amount	Sqz Amount	Stretch	Amplify
P1v1	157.9	159.3	273.6	91.9	123.8	50.0	2.5	0.19	0.38	-0.05	10.0
P2v1	164.2	167.1	574.0	47.8	0.0	50.0	30.0	-0.10	-0.21	0.50	10.0
P3v1	137.9	154.7	204.6	104.2	627.5	50.0	0.0	0.50	1.00	-0.04	10.0
P4v1	40.6	90.1	53.2	68.7	41.3	50.0	20.1	-0.10	-0.19	-0.16	10.0
P5v1	107.1	177.5	490.2	38.8	0.0	5.0	30.0	0.22	0.44	-0.01	10.0
P6v1	230.2	176.4	167.6	242.2	602.7	50.0	0.0	-0.08	-0.16	-0.17	10.0
P7v1	35.5	48.0	228.1	7.5	0.0	50.0	30.0	-0.03	-0.05	0.03	10.0
P8v1	126.9	117.5	261.5	57.0	751.4	50.0	0.0	0.44	0.88	0.11	10.0
P9v1	194.6	212.6	350.8	117.9	0.0	50.0	9.1	0.23	0.46	-0.05	10.0

Low rank

Concept	Size				Twist		Bend	Squeeze		Stretch	
Random	X	Y	Z	X*Y/Z	Angle	Bias	Angle	Bulge Amount	Sqz Amount	Stretch	Amplify
P1v2	51.6	42.8	222.1	9.9	266.0	45.0	19.0	-0.06	-0.48	0.41	5.0
P2v2	129.1	58.5	1073.6	7.0	679.0	35.0	5.0	0.45	-0.24	0.45	5.0
P3v2	219.7	218.8	392.2	122.6	90.0	25.0	28.0	0.33	-0.27	-0.37	4.0
P4v2	250.9	245.2	505.8	121.6	1.0	9.0	11.0	0.35	-0.19	-0.16	9.0
P5v2	204.7	119.9	620.5	39.6	77.0	34.0	26.0	0.30	-0.33	-0.22	3.0
P6v2	104.1	67.0	544.2	12.8	59.0	20.0	17.0	0.07	0.72	0.28	5.0
P7v2	163.8	121.4	696.5	28.6	65.0	36.0	20.0	0.15	0.57	0.39	2.0
P8v2	193.2	118.7	414.2	55.4	431.0	24.0	27.0	0.01	0.07	0.27	10.0
P9v2	95.0	65.4	613.6	10.1	841.0	43.0	4.0	0.14	-0.15	0.42	6.0

	X	Y	Z	X*Y/Z	Angle	Bias	Angle	Bulge Amount	Sqz Amount	Stretch	Amplify
	38.5	56.3	241.6	9.0	0.0	50.0	23.1	-0.20	-0.40	0.43	10.0
	205.2	180.9	444.5	83.5	51.0	45.0	8.0	0.40	-0.32	-0.42	6.0
	107.1	177.5	490.2	38.8	0.0	5.0	30.0	0.22	0.44	-0.01	10.0
	250.9	245.2	505.8	121.6	1.0	9.0	11.0	0.35	-0.19	-0.16	9.0
Mean: A:	150.4	165.0	420.5	63.2	13.0	27.3	18.0	0.19	-0.12	-0.04	8.8
Stdev:	95	70	122	50	25	24	10	3.07	2.64	2.82	2

	X	Y	Z	X*Y/Z	Angle	Bias	Angle	Bulge Amount	Sqz Amount	Stretch	Amplify
	77.3	131.1	80.1	126.6	0.0	50.0	0.0	-0.10	-0.19	-0.35	10.0
	126.9	117.5	261.5	57.0	751.4	50.0	0.0	0.44	0.88	0.11	10.0
	406.2	365.1	122.4	1211.5	479.0	35.0	24.0	-0.08	0.20	-0.28	7.0
	95.0	65.4	613.6	10.1	841.0	43.0	4.0	0.14	-0.15	0.42	6.0
Mean: B:	176.4	169.8	269.4	351.3	517.9	44.5	7.0	0.10	0.19	-0.03	8.3
	155	133	242	575	378	7	11	3.07	2.01	2.81	2
A-B:	-26.0	-4.8	151.1	-288.1	-504.9	-17.3	11.0	0.09	-0.30	-0.01	0.5
A/B:	85%	97%	156%	18%	3%	61%	258%	189%	-64%	147%	106%

Parametric comparison of SER and WER concepts from the Main Study.

Main Study

Concept	Size X	Size Y	Size Z	X*Y/Z	Twist Angle	Twist Bias	Bend Angle	Squeeze Bulge Amount	Squeeze Sqz Amount	Stretch Stretch	Stretch Amplify
Manual											
P1v1	153.0	78.8	291.5	41.4	0.0	50.0	0.0	0.29	0.59	0.11	10.0
P2v1	38.5	56.3	241.6	9.0	0.0	50.0	23.1	-0.20	-0.40	0.43	10.0
P3v1	166.9	255.4	532.7	80.0	528.5	50.0	0.0	0.35	0.71	0.11	10.0
P4v1	265.4	182.5	299.1	162.0	330.0	50.0	8.5	0.17	0.33	-0.08	10.0
P5v1	93.9	100.3	155.2	60.7	388.1	50.0	0.0	0.22	0.44	-0.11	10.0
P6v1	71.7	97.7	373.2	18.8	0.0	50.0	10.7	0.12	0.23	0.50	10.0
P7v1	71.7	97.7	373.2	18.8	355.1	50.0	30.0	0.47	0.94	-0.16	10.0
P8v1	77.3	131.1	80.1	126.6	0.0	50.0	0.0	-0.10	-0.19	-0.35	10.0
P9v1	182.4	93.1	180.3	94.2	99.1	50.0	14.6	-0.14	-0.28	-0.08	10.0
Random											
P1v2	130.9	155.1	273.6	74.2	149.0	7.0	14.0	0.23	-0.46	-0.24	10.0
P2v2	315.7	131.0	240.1	172.3	37.0	5.0	30.0	0.15	-0.26	-0.10	10.0
P3v2	102.3	136.4	336.3	41.5	224.0	39.0	13.0	0.31	-0.39	-0.17	7.0
P4v2	153.4	129.9	545.2	36.5	227.0	19.0	22.0	0.38	0.43	0.06	8.0
P5v2	171.8	78.6	372.5	36.2	489.0	24.0	25.0	0.43	-0.24	-0.17	4.0
P6v2	406.2	365.1	122.4	1211.5	479.0	35.0	24.0	-0.08	0.20	-0.28	7.0
P7v2	205.2	180.9	444.5	83.5	51.0	45.0	8.0	0.40	-0.32	-0.42	6.0
P8v2	312.4	249.8	400.2	195.0	57.0	45.0	7.0	0.19	-0.18	-0.37	6.0
P9v2	839.6	409.6	101.1	3401.9	142.0	40.0	30.0	-0.04	-0.17	-0.42	8.0

High rank (green) / Low rank (red)

Verification Study

Concept	Size X	Size Y	Size Z	X*Y/Z	Twist Angle	Twist Bias	Bend Angle	Squeeze Bulge Amount	Squeeze Sqz Amount	Stretch Stretch	Stretch Amplify
Manual											
P1v1	157.9	159.3	273.6	91.9	123.8	50.0	2.5	0.19	0.38	-0.05	10.0
P2v1	164.2	167.1	574.0	47.8	0.0	50.0	30.0	-0.10	-0.21	0.50	10.0
P3v1	137.9	154.7	204.6	104.2	627.5	50.0	0.0	0.50	1.00	-0.04	10.0
P4v1	40.6	90.1	53.2	68.7	41.3	50.0	20.1	-0.10	-0.19	-0.16	10.0
P5v1	107.1	177.5	490.2	38.8	0.0	5.0	30.0	0.22	0.44	-0.01	10.0
P6v1	230.2	176.4	167.6	242.2	602.7	50.0	0.0	-0.08	-0.16	-0.17	10.0
P7v1	35.5	48.0	228.1	7.5	0.0	50.0	30.0	-0.03	-0.05	0.03	10.0
P8v1	126.9	117.5	261.5	57.0	751.4	50.0	0.0	0.44	0.88	0.11	10.0
P9v1	194.6	212.6	350.8	117.9	0.0	50.0	9.1	0.23	0.46	-0.05	10.0
Random											
P1v2	51.6	42.8	222.1	9.9	266.0	45.0	19.0	-0.06	-0.48	0.41	5.0
P2v2	129.1	58.5	1073.6	7.0	679.0	35.0	5.0	0.45	-0.24	0.45	5.0
P3v2	219.7	218.8	392.2	122.6	90.0	25.0	28.0	0.33	-0.27	-0.37	4.0
P4v2	250.9	245.2	505.8	121.6	1.0	9.0	11.0	0.35	-0.19	-0.16	9.0
P5v2	204.7	119.9	620.5	39.6	77.0	34.0	26.0	0.30	-0.33	-0.22	3.0
P6v2	104.1	67.0	544.2	12.8	59.0	20.0	17.0	0.07	0.72	0.28	5.0
P7v2	163.8	121.4	696.5	28.6	65.0	36.0	20.0	0.15	0.57	0.39	2.0
P8v2	193.2	118.7	414.2	55.4	431.0	24.0	27.0	0.01	0.07	0.27	10.0
P9v2	95.0	65.4	613.6	10.1	841.0	43.0	4.0	0.14	-0.15	0.42	6.0

High rank (A)

	X	Y	Z	X*Y/Z	Angle	Bias	Angle	Bulge Amount	Sqz Amount	Stretch	Amplify
	38.5	56.3	241.6	9.0	0.0	50.0	23.1	-0.2	-0.4	0.43	10.0
	164.2	167.1	574.0	47.8	0.0	50.0	30.0	-0.1	-0.2	0.50	10.0
	171.8	78.6	372.5	36.2	489.0	24.0	25.0	0.4	-0.2	-0.17	4.0
	204.7	119.9	620.5	39.6	77.0	34.0	26.0	0.3	-0.3	-0.22	3.0
Mean A:	144.8	105.5	452.2	33.1	141.5	39.5	26.0	0.11	-0.29	0.14	6.8
Stdev:	73	40	177	17	234	13	3	3.28	11.50	2.62	4

Low rank (B)

	X	Y	Z	X*Y/Z	Angle	Bias	Angle	Bulge Amount	Sqz Amount	Stretch	Amplify
	77.3	131.1	80.1	126.6	0.0	50.0	0.0	-0.1	-0.2	-0.35	10.0
	157.9	159.3	273.6	91.9	123.8	50.0	2.5	0.2	0.4	-0.05	10.0
	839.6	409.6	101.1	3401.9	142.0	40.0	30.0	0.0	-0.2	-0.42	8.0
	219.7	218.8	392.2	122.6	90.0	25.0	28.0	0.3	-0.3	-0.37	4.0
Mean B:	323.6	229.7	211.8	935.8	89.0	41.3	15.1	0.10	-0.06	-0.30	8.0
Stdev:	340	125	148	1644	63	12	16	5.01	3.33	5.07	3
A-B:	-178.9	-124.2	240.4	-902.6	52.5	-1.8	10.9	0.01	-0.23	0.43	-1.3
A/B:	45%	46%	214%	4%	159%	96%	172%	111%	465%	-45%	84%

Appendix: S - Conference Publications and Posters

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION, 2 - 3 SEPTEMBER 2010, NORWEIGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY, TRONDHEIM, NORWAY

RESEARCHING FIRST CONTACT EMOTIONAL RESPONSES TO PRODUCTS

Tim Reynolds

Bournemouth University

Keywords: Design, aesthetics, semiotics, emotion

Summary of paper

This paper provides an overview of ongoing research at the inception stage of a PhD research project in the area of design and emotion, and discusses some of the key issues that have arisen out of the research to date. It outlines a pilot study that is planned to identify further avenues of research and considers the implications of the research on design education. The paper is part of research being developed by the Creative Design Research Group and taught on design courses, in the School of Design, Engineering and Computing at Bournemouth University. The paper illustrates how this can support the education and development of product and engineering design students in design education.

For products to enjoy long term commercial success in today's society they need to possess more than mere functional adequacy and pleasing aesthetics. Consumers are now presented with a huge array of product choices; each design offering slightly different features from those of their competitors, or at least similar ones at a lower price. Users experience different emotional responses towards products at different times. However, a particularly significant time in a persons' emotional relationship with a product is at the moment of first-contact. It is at these times that a product is seen for the first time and when an emotional response can be evoked in the consumer that could make the difference between whether or not they choose to purchase or use that product. At this point, the investment a company has made in the design, development, manufacture, and marketing of their product lies in the balance. The design that evokes the right emotional response in the consumer at the right time is the one that the consumer is most likely to purchase.

The emotional aspect of design has broad scope and there has been considerable debate in recent years with regard to the way in which products can elicit different emotions and subsequently how people are attracted to the products around them. The particular area of interest for this research is that of the emotional responses evoked by *first-contact* with products. Specifically for the purposes of this research, the term *first* is used here to mean at a point which a potential consumer has no prior awareness of the product, and *contact* meaning visual contact rather than through physical touch.

Different people can experience different emotions in relation to the same product. Therefore, designing products that can elicit a particular emotional response is difficult. But compared to other aspects of design, emotions are no less important in view of the impact they can have on a consumer's decision making process at the point of product selection and purchase. Providing designers with the necessary insight into how people's emotional experiences are affected during first-contact encounters with products should enable them to elicit user's emotions more coherently. Design, semiotics and knowledge generated in the fields of psychology and communication provide a useful basis for research into how this insight might be acquired. Some current perspectives on design and emotions and the way in which this research relates to product design education have been discussed here. In parallel, a pilot study has been outlined that may help to explore the role design plays in eliciting particular emotions at first contact. A more focused line of research will follow analysis of data from that study.

Bournemouth University

Tim Reynolds - School of DEC
PhD Supervisors: Prof. Siamak Noroozi & Dr Bob Eves

FIRST CONTACT EMOTIONAL RESPONSES TO PRODUCTS

First Contact with a Product
People have emotional relationships with products that can vary from person to person and change over time. A persons' emotional relationship with a product at the moment of first-contact is when a product is seen for the first time and when a significant emotional response can be evoked in a potential consumer or user. For the purposes of this research, the term *first* is used to mean at a point which a potential consumer has no prior awareness of the product, and *contact* meaning visual contact rather than exclusively through physical touch.

Eliciting Emotions through Design
Emotional responses can be evoked through aesthetics and design semiotics (the science of signs). Saussure demonstrated that meaning is signified as a result of aspects of signs known as signifiers (Cobley & Jansz 1999). Products can be signifiers and can have signifiers represented within them. When a person reflects on their experiences with a product, those meanings have time to establish themselves and the relationship with that product develops (Eves & Hewitt 2008).

Processing Emotions
Norman (Norman 2004) describes a model of emotional processing that consists of visceral, behavioural and reflective processes linked to sensory inputs and motor control outputs (Fig.1). The visceral level deals with instinctive reactions that occur during a new encounter. The behavioural level, where conscious decisions are made, can influence the visceral level and can subsequently be influenced by the reflective level. Experiences are revisited at the reflective level after they have happened, and while reflection is not linked directly to the senses, it has a significant influence on how a similar experience might be dealt with in the future.

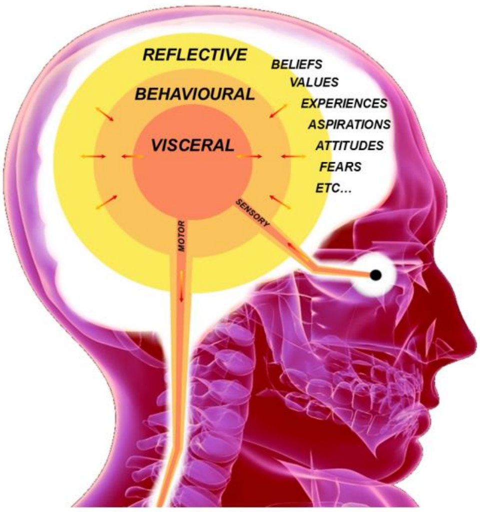
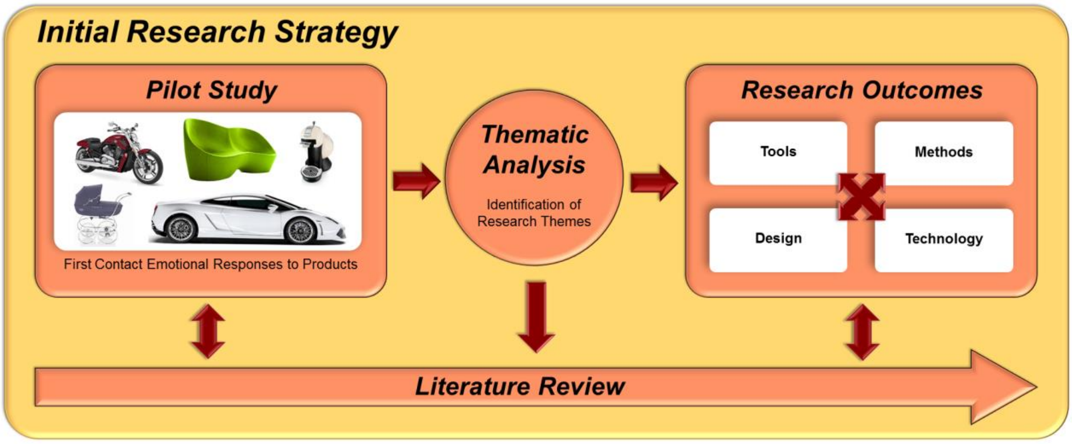


Figure 1. Three levels of emotional processing

The Aim of this Research
The aim of this research to develop a method or tool that will better enable designers to understand and design for peoples' emotional needs and to bridge the gap between the emotions experienced at first contact and those that develop over time, through reflection. It sets out by seeking to establish the emotional responses that people experience when they encounter a product for the first time. An initial qualitative pilot study was undertaken in April/May 2010 to gather this data and to identify themes for further research.

An ongoing literature review has identified a growing academic and industrial interest in this field and the need for '*Rigorous and reliable methodologies that can be applied to common tasks in industrial product development…*' (ENGAGE 2005). It is envisaged that the outcomes of the pilot study will inform the future direction of the research in conjunction with information gathered through the literature review.



References
Cobley, P. and Jansz, L., 1999, Introducing Semiotics, Icon Books Ltd
Eves, B and Hewitt, H. Semiotics, 2008, Design Character Language, *10th International Engineering and Product Design Education Conference, 4-5 September 2008, Barcelona*
Norman, D.A., 2004, Emotional Design; Why We Love (or Hate) Everyday Things. Basic Books Ltd
ENGAGE Consortium, July 2005, Engineering Emotional Design – Report on the State of the Art

Bournemouth University

AUGMENTING AFFECTIVE AESTHETICS IN DESIGN CONCEPTS

Tim Reynolds - School of DEC PhD Supervisors: Prof. Siamak Noroozi & Dr Bob Eves

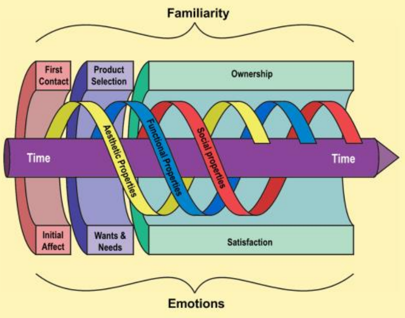
Context , Aim and Objective of this Research

Designers *want to design experiences and generate pleasurable or exciting sensations* (Hekkert 2002). But the emotional response that an individual experiences in relation to a product design may often depend on:

1) The individual's familiarity with the product or type of product.
2) The degree to which the product's design meets the expectations and aspirations of the individual.

The semiotics (Cobley and Jansz 1999) and referential semantics (Demirbilek and Sener 2003) of a product help to communicate information about it visually, especially at first contact when there may be little other information or experience to draw upon (see opposite).

The aim of this PhD research project is to assist designers in eliciting emotional responses through design aesthetics, particularly at first contact. The specific objective is to develop a design tool that can augment affective aesthetic form in product design concepts within a given product domain.



A CAD Tool

The types of emotional affect that designers seek to elicit through their concepts can be diverse across a broad array of product genres.

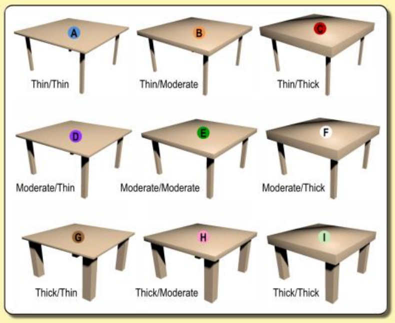
The initial proposal is for a CAD tool that can apply and manipulate geometric transformations within the CAD model's hierarchy using verbal descriptors in order to enhance the aesthetic affect of a given concept.

Initial Study

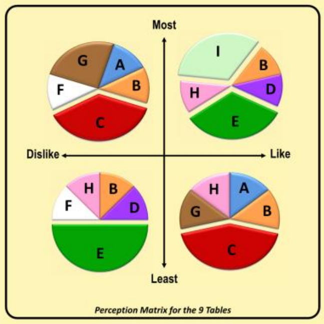
A range of table concepts was generated in CAD with all but two identical attributes:

i) Table Top Thickness

ii) Table Leg Thickness



The results of the study indicated that there was a significant level of accordance between participants:



A questionnaire was distributed online, in which participants were asked to:

a) Indicate their emotional response (via 5-point Likert scale) to each table.

b) Indicate which designs they liked *most* and *least* from groups of three tables.

Tables 'E' and 'I' were perceived to possess the most positive affect while table 'C' the least, demonstrating the potential for a design tool as outlined above to be used to evoke an emotional response to product aesthetics within a CAD environment.

The next stage of this research will be to undertake a new study in which participants take on the role of designer, interacting with and modifying a CAD concept via a dedicated user interface in order to achieve a predetermined emotional affect.

References
Cobley, P. and Jansz, L., 1999, Introducing Semiotics, Icon Books Ltd
Demirbilek, O. and Sener, B., 2003, Product design, semantics and emotional response, *Ergonomics*, 2003, vol46, pp, 1346-1360,
Hekkert, P. 2002, Announcement of the 3rd Design and Emotion Conference, 2002

www.bournemouth.ac.uk

16 A design tool for the augmentation of geometric aesthetic affect

Candidate Name: Tim Reynolds

Supervisors: Siamak Noroozi, Bob Eves

Affiliation: Design Simulation

This PhD research project sets out to investigate the augmentation of affective aesthetic form in product design concepts, for designers to elicit positive emotional responses from their designs. The aesthetic concepts that can be generated for a particular design brief can be limitless. Multiple concepts may result from a designer's creative endeavours and from the combination and reinterpretation of earlier concepts. This can be a time consuming process where a rational and logical approach may not find new ways of looking at the emotional aspects of design. There is potential for a design tool with the capacity to generate many aesthetic concepts quickly, within parametric constraints, which are surprising or unexpected. The presentation will outline the project's progress to date (currently at the post MPhil Transfer stage) and discuss to what extent a design tool could elicit enhanced emotional responses by augmenting product design concepts using random functions.