EVALUATING INTUITIVE INTERACTIONS USING IMAGE SCHEMAS

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Doctor of philosophy

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DECLARATION

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This work has not previously been accepted in substance for any degree and is not concurrently submitted in candidature for any degree.

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ABSTRACT

Intuitive use is a desirable feature in interface design. In the last decade, researchers have made considerable progress in developing approaches for design for intuitive use. Most of the current approaches, however, have been limited to qualitative exploration, in the form of providing guidelines aimed to help designers to design products that are intuitively useable. This thesis focusses on developing a quantitative approach for evaluating intuitive interaction with the help of *image schemas*. An image schema is a recurring structure within the human cognitive system that establishes patterns of reasoning with the physical world. Researchers have found this concept to be very useful in capturing human interaction with products; it is also suitable for analysing product features. The approach developed in this thesis measures intuitive interaction based on the degree of match (known in this study as *quantification*, 'Q') between the designer's intent and the users' interaction both expressed through image schemas. The value of the proposed approach is in the provision of measurable outputs for evaluating intuitive interaction. The proposed approach is evaluated through an empirical study designed to test the validity of 'Q' as a measure of intuitive use expressed through task completion time, errors and cognitive effort. The results reveal that participants with high 'Q' value were significantly quicker, made fewer errors, and expended less cognitive effort while completing all subtasks with the three products used in the study.

Secondly, the thesis addresses the limitation of other studies in the applicability of the methods used for extracting image schemas. Previous approaches have predominantly relied on the expertise of the researcher conducting the study in extracting the identified image schemas from the utterances of the users. This could introduce subjective bias, thereby reducing the reliability of the method for extracting image schemas. This study addressed this limitation by developing a systematic approach based on a novel algorithm for extracting image schemas from users' utterances. This enhanced image schema extraction method is based on the use of two ontologies: a lexical ontology and a domain-specific ontology (image schema ontology). The domain-specific ontology was purpose-built for the needs of this study. The independent evaluation study conducted to evaluate the algorithm revealed a substantial strength with an overall k of 0.67 across the 3 products used in the study.

Previous studies have predominantly focussed on the *cognitive* aspect of intuitive use. A limited amount of work has explored the *affective* aspect of intuition, and integrated it into the evaluation of intuitive use. This study addressed this limitation by developing a novel approach for assessing the affective aspect of the intuitive use of products. This novel approach incorporates the enhanced algorithm for extracting image schemas that was developed for this study. In addition, a sentiment analysis on the affective words linked to the image schemas employed in the task is used as part of the evaluation process. The proposed approach is evaluated through an empirical study based on the sentiments used in describing the image schemas employed for the interaction. The results show that the approach links the image schemas used for the completion of a task to the affective experiences of the users. This has potential to lead to significant improvements in design for intuitive use because it allows experiences to be linked directly to the specific image schemas employed in the design.

Overall, the study contributes significantly to the knowledge in this field by validating a new quantitative approach for evaluating intuitive interactions with physical objects. The approaches developed in this study will enable designers to evaluate intuitive usage at different phases of the design process.

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ANOVA	Analysis of variance (statistical parameter)
ATS	Activation trigger schema (Fischer et al, 2009)
GALC	Geneva affects label coder (Sherer, 2005)
HCI	Human computer interaction
ISCAT	Image schema catalogue (database of image schemas)
ISO	International standardisation organisation
IUUI	Intuitive use of user interface (research group)
k	Strength of agreement (Cohen kappa)
M	Mean
OntoRo	Lexical ontology based on Roget Thesaurus
p	Probability
PMA	Perceptual meaning analysis (Mandler, 1992, 2005)
Q	Quantification (measure of intuitive use)
SD	Standard deviation
UCD	User centred design
UI	User interface
UID	User interface design
UX	User experience
WWW	World Wide Web

LIST OF PUBLICATIONS

Journal Publications

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CHAPTER 1
INTRODUCTION

1.1 MOTIVATION

Multifunctional products have penetrated all aspects of our life. It was once estimated that each person in the Western world uses some twenty thousand different objects (each with its own interface), most of which are highly specialised and require learning (Norman, 1993). New interfaces with ever-more sophisticated features and functionality appear every day. This trend has a negative impact on users, as unfamiliar interfaces increase the cognitive effort required during interaction with products (Blackler et al., 2010). Over the last decade, the problem has been aggravated due to market demands and high consumer expectations. One way of managing such complexity is to employ principles that facilitate intuitive use.

Researchers have generally accepted that intuition is based on past experience (Bastick, 1982; Agor, 1986; Hammond, 1987; Klein, 1998; Hogart, 2001; Kahneman, 2003; Sinclair and Ashkanasy, 2005; Blackler et al., 2010). They differ, however, on how this knowledge is stored and retrieved from long-term memory. While some researchers consider intuition as an experiential-based process that is purely cognitive (Simon, 1987; Klein, 1993; Hogarth, 2001), others allude to the fact that *affect* plays a role in the process (Bastick, 2003; Sinclair and Ashkanasy, 2005). These researchers' position is supported by evidence from somatic marker theory (Damasio, 1994), affects heuristics (Finucane et al., 2000; Keller et al., 2006) and intuitive thought theory (Bastick, 2003). These theories postulate a way in which affect can be stored with the experiential knowledge that can be used as part of the retrieval process.

This research considers intuition as a processing mode, which comprises both cognitive and affective elements (Sinclair and Ashkanasy, 2005). The term "affect" is defined as the emotion that is consequent upon an interaction which is encoded in the previous experiences of the user. Two aspects are central in this approach: the cognitive and the affective elements in the application of previous knowledge. The first aspect presumes that less cognitive effort is required to identify a solution if the information processing is based on the non-conscious scanning of stored knowledge. The affective aspect, which is the emotion that results from the interaction, is also an integral part of intuitive interaction. Based on the context, this aspect either facilitates or inhibits access to previously acquired knowledge (Sinclair et al., 2002).

Intuition has been researched in psychology for several decades, and much of the research is empirical. It is only recently that the field of HCI has begun appropriating the concept of intuition. Several researchers have discussed the concept of intuitive use in the fields of HCI and design (Raskin, 1994; Cooper, 1995; Frank and Cushcieri, 1997; Lehikoinene and Roykkee, 2001; Vroubel et al., 2001; Rosson and Carrol, 2002; Dixon and O'Reilly, 2002 and Spool, 2005). None of these studies, however, have explained how the mechanism of intuition is related to product use.

Intuitive use is generally understood as an experience where a user immediately uses a new interface successfully based on his prior knowledge of other products (Blackler, 2003a). The concept is used more often as a desirable quality criterion for user interface requirements by designers and frequently demanded by users. It is not surprising, that the concept has emerged as a specific field of research within HCI with a particular high rate of interest within the last decade. Nowadays, the concept is mostly employed by marketers as a selling proposition to invite user to their product. According to O'Brien (2010), this aspect is quite acceptable as an advertising tool to attract customers, but poses a serious problem for the designer of the product in delivering the expectation.

These demands of intuitive use are often difficult to meet when several technologies are located in the same device. For example, mobile phones have been equipped with different functionality comprising games, cameras and various softwares. According to Hurtienne

(2009), as the cognitive demand of using new technologies grows, the need for intuitive use grows accordingly. Providing documentation cannot address the problem of intuitive use as it has been found that people try things out on their own and try to relate what they already know to the current situation (Rettig, 1991). They are likely not to attend any training classes to learn about the product. If the device is designed to be intuitively useable, the need for training will be reduced.

Until recently, there has been limited research studies on how people use things intuitively and how exactly designers can make an interface intuitive. Australian and the German research groups have pioneered several empirical studies which have formed the foundation of the understanding of intuitive interactions (Blackler and Hurtienne, 2007). Over the last decade, several researchers have explored the concept using a variety of products ranging from simple [VCR, remote control, microwave, alarm clock] to complex [Airbus 320 cockpit, on board computer of an automobile, ticket and cash machines] (Blackler, 2003a, 2003b, Hurtienne and Blessing, 2007; Blackler and Hurtienne, 2007, Antle et al, 2009; Fischer et. al, 2009; Britton et al, 2013; O'Brien et al 2010). They have all found that intuitive interactions is strongly linked with familiarity and prior experience and can be useful within HCI as a means of designing and evaluating simple and complex interfaces (Blackler, 2010, Fischer et al, 2009, 2015, Hurtienne and Blessing, 2009; O' Brein, et al, 2010, Britton et al, 2010).

Previous studies have explored several theories that support design for intuitive use. These theories include affordances, population stereotype, metaphor, gestalt laws, and consistency (Moh's et al., 2006; Blackler and Hurtienne, 2007). Despite their usefulness, however, many of these theories have limitations. For example, gestalt law is restricted to the arrangement of features, which is a very narrow area of design, and population stereotype is not universal in its application. Current trends that support the concept of intuitive use include user experience design, product semantics, sentiment analysis and opinion mining. These theories explore diverse aspects of human experiences, including both the cognitive and the affective aspects, which is the focus of this study.

In the field of user interface design, current approaches to designing and evaluating intuitively useable interfaces exploit the idea that the use of prior knowledge enables quicker cognitive processing (Hurtienne and Blessing, 2007; Blackler et al., 2010). Specifically, most of the approaches for exploring intuitive use have been based on the cognitive aspect of intuition (Hurtienne and Blessing, 2007; Fischer et al., 2009; Blackler et al., 2010; Antle et al., 2011; Britton et al., 2013; Asikhia et al., 2015). In contrast, the affective aspect has received less attention (O'Brien et. al., 2010).

To date, all most all the intuitive use design frameworks emanate from the continuum of intuitive interactions developed by the Australian research group and the continuum of prior knowledge developed by the German group (Blackler and Hurtienne, 2007). The continuum of intuitive interactions (Blackler et al., 2006) proposes three principles for creating intuitive interfaces. These are: (i) use familiar features for well-known functions; (ii) transfer familiar things from other domains and (iii) increase redundancy and internal consistency of function, appearance and location with the interface. The first principle, for example, involves applying existing features, symbols and icons from the same domain and putting them in a familiar position. The second principle relates to the use of metaphors and familiar functions from other domains. The third principle involves using visual and audible feedback, and providing alternative ways of accomplishing a task so that both novices and experts, as well as older and younger users, can use the same interface easily and efficiently. Keeping internal consistency allows users to apply the same knowledge and metaphors throughout the interface.

The continuum of prior knowledge (Blackler and Hurtienne, 2007) acquired before interaction with new products comes from a variety of sources (Hurtienne and Israel, 2007) including innate knowledge, sensorimotor skills, culture, expertise and the use of tools. The potential number of people possessing a particular type of knowledge in the continuum of knowledge decreases from the bottom to the top. In other words, the lower the level of knowledge in the continuum, the more widely available it is. These lower levels of knowledge are more likely to be used unconsciously and therefore intuitively.

Anchoring his work on the sensorimotor level in the continuum of prior knowledge, Hurtienne (2009), suggests the use of image schemas and their metaphoric extensions as a means of exploring the concept of intuitive use. He proposes that image schema supports the correct metaphoric mapping between the layout and function of an interface. Thus, products that conform to image schematic thinking are easier to understand (Hurtienne and Isreal, 2007). Other researchers that have applied specific aspect of the continuum of knowledge for exploring intuitive use include (Fischer et al, 2009; 2015, Antle et al, 2011; Britton et al, 2013; "IBIS" (The German form of IU with image schema, Loeffer et al, 2013).

Intuitive interaction is operationalised using different methods. While the German research group employs International Organization for Standardization, ISO usability standard (ISO, 1998), which employs effectiveness, efficiency and satisfaction, the Australia group uses time on task, and intuitive first use. Although, the two approaches shows a lot of similarities as time on task is used as an indicator for efficiency and the number of errors for effectiveness. The major difference is in the cognitive effort adopted by the two groups. The German group uses a structured questionnaire for the cognitive effort while the Australian group uses verbalisation or lack of it as a means of identifying the cognitive processes adopted for the completion of the task.

These current approaches are mostly limited to qualitative exploration in the form of providing guidelines aimed at helping designers to design products that are intuitively usable. The only exception is the work conducted by Blackler et al., (2003a; 2003b) who developed an approach for computing intuitive use based on technology familiarity scores. The score is computed based on the participants' rating of similar technology that they have used in the past. Despite this study's contribution, the approach is limited, as the method used for computing the score based on the familiarity of the participants with previous technology they have used in the past is subjective. While these studies are commendable, as they provide a foundation upon which the concept of intuitive use can be abstracted further, these findings have nevertheless, created opportunities for more studies, including the quantitative evaluation of intuitive interaction.

A few studies exploring the cognitive aspects of intuitive interaction have recently used the concept of image schemas, which several researchers have advocated as an approach for exploring the concept of intuitive use (Mohs et al., 2006; Hurtienne, 2011; Maracanas et al., 2012; Asikhia et al., 2015). An image schema is defined as a recurring structure within the cognitive system that establishes patterns of understanding from bodily interaction (Johnson, 1987). These recurring structures facilitates the transfer of knowledge from one domain to another. The theory originated from cognitive linguistics and is linked to metaphor. Several studies on image schemas conducted in the fields of cognitive linguistics and psychology (Stanfield and Zwaan, 2001; Glover et al., 2004; Zwaan and Taylor, 2006) have shown that the concept can be instantiated in audio, visual and motor modalities, and that the use of image schemas has potential for use in the design and evaluation of intuitive interfaces.

A limited number of studies have explored this potential in the fields of HCI and design, however, even though image schemas have been found to be very useful in describing the interface feature. Examples of products used in studies include cameras (Kuhn and Frank, 1991); tangible interface called a 'memory box' (Hurtienne and Israel, 2007); Airbus 320 cockpit (ISCAT, 2012) and alarm clocks, the subject of the current study (Asikhia et al., 2015). Methods used in analysing the interfaces include direct observation (Antle et al., 2011; Britton et al., 2013) and analysing the utterances of participants while completing a task (Maglio and Matlock, 1999; Raubal and Worboys, 1999; Hurtienne, et al., 2008; Hurtienne and Langdon, 2010). In all of these studies, image schemas were extracted based on the expertise of the researcher conducting the study.

An analysis of the previous studies reveals that image schemas can be identified and extracted from the point of view of a designer or user. The designer's perspective can be identified and extracted by analysing the interface features or product description (Hurtienne and Israel, 2007; Hurtienne et al., 2008, ISCAT, 2012; Asikhia et al., 2015). The image schemas employed by the users (the user's perspective) can be identified and extracted from direct observations (Hurtienne and Blessing, 2007; Antle et al., 2011; Britton et al., 2013) and utterances (Maglio and Matlock, 1999; Hurtienne and Langdon, 2010).

An analysis of previous studies also shows three significant research gaps that limit the use of image schemas as a research tool:

(1) A methodology for determining whether or not the evaluation of an interaction is intuitive in quantitative terms is currently still unavailable. A quantitative approach for measuring intuitive interaction would help designer to design products that are intuitively useable.

(2) The use of personal expertise to identify and extract image schemas increases the likelihood of introducing subjective bias, thereby reducing the reliability of the assessment. The availability of a systematic approach to extracting image schemas would greatly facilitate the reliability of the use of image schemas as a means for the design and evaluation of intuitive use.

(3) Previous studies have predominantly focussed on the cognitive aspect of intuitive use. There has been limited work exploring the affective aspect of intuition, and integrating this aspect into the evaluation of intuitive use. Utilising the affective aspect of intuition would be beneficial in the evaluation of intuitive use.

Consequently, this research proposes to address the aforementioned problems in two parts, broken down into four objectives. The first part proposes a quantitative approach for evaluating intuitive interaction with products. The quantitative approach integrates previous methods used in extracting image schemas, and examines the different contributions of each of the identified methods. This approach is significantly different from others, as it quantifies intuitive interactions based on the degree of match between the designer's intent and the users' interaction, both expressed through image schemas.

The second part proposes an approach for assessing the affective aspect of intuitive interactions with products. The approach incorporates, in a systematic and analytical way, the affective aspect of intuition as part of the evaluation process. In particular, the approach includes a novel algorithm developed to extract the image schemas used to complete the task, a domain-specific ontology of image schemas specifically developed for the needs of the study, and a sentiment analysis conducted in order to classify the polarity of the affective words linked to the image schemas used in performing the task.

1.2 AIM AND OBJECTIVES

The overall aim of this research is to develop a quantitative approach for evaluating intuitive interactions based on image schemas. The study proposes an evaluation approach based on the comparison between the designer's intent and the user's interactions, both expressed through image schemas.

The research objectives include:

(i) To develop and validate a quantitative approach for measuring intuitive interactions with products;

(ii) To propose and evaluate an algorithm for extracting image schemas from users' utterances.

(iii) To develop an image schema ontology, used as the knowledge base for the algorithm;

(iv) To develop and validate an approach for evaluating the affective aspect of design for intuitive use.

1.3 OUTLINE OF THE THESIS

Chapter 2 reviews the relevant literature on the nature and process of intuition and relates the understanding to design for intuitive use. In addition, it reviews the current state-of -the art methodological tools for the design and evaluation of intuitive use, and it examines the current theories and principles that could contribute to design for intuitive use. Finally, Chapter 2 explores image schema theory, and its suitability for meeting the needs of intuitive use.

Chapter 3 describes the research methodology employed in the study. In addition, it highlights the research instrument and shows how the instrument is a good match for the study. Finally, the chapter describes the process used to analyse the data.

Chapter 4 introduces the conceptual framework developed for evaluating intuitive interactions. The chapter describes the methodology for the development of the framework, and how the components fit into significant studies that have been conducted in this area; it also describes the distinctions of the proposed framework from other frameworks in the area.

Chapters 5–7 address the four objectives listed above, as follows.

Chapter 5 addresses objective (1). It describes in detail the empirical study conducted, and illustrates how the proposed approach can be concretely applied to measure intuitive interaction in a set of products. The chapter also describes how the decision rules, in conjunction with the inter-rater reliability test, were used to determine image schemas extracted from multiple methods used in the analysis. Finally, Chapter 5 evaluates the validity of the proposed approach in accounting for intuitive use (as measured by low task completion times, errors, and cognitive effort) based on the statistical tests conducted.

Chapter 6 addresses objectives (2) and (3). It starts by introducing the algorithm for extracting image schemas from user-transcribed speech. The algorithm addresses the limitations in previous methods used for extracting image schemas, which to date have been based on the personal expertise of the researcher conducting the study. The proposed algorithm employs a structured approach, and utilises two ontologies: lexical and domain-specific. In addition, this chapter describes the process involved in developing the ontology, and how it is utilised. Finally, the accuracy of the extracted image schemas correctly identified by the algorithm to be relevant for the task is evaluated based on human expert judgement.

Chapter 7 addresses objective (4). It starts by introducing the approach for evaluating the affective aspect of design for intuitive use based on image schemas. In addition, the chapter describes how the algorithm developed for extracting image schemas from users' utterances in Chapter 6 was deployed in the approach. Furthermore, the chapter illustrates how the approach was used in evaluating the affective aspect of intuitive use in products based on the third empirical study conducted. Finally, the approach is evaluated in Chapter 7 based on the sentiments expressed in the use of the image schemas identified for performing the task.

Chapter 8 summarises the contributions of this study, draws conclusions, and discusses possible future research directions.

CHAPTER 2

LITERATURE REVIEW

This chapter reviews the theoretical foundations and attributes of intuition; it describes the role of intuition and how the knowledge is appropriated in design for intuitive use. This chapter reviews the current state-of-the-art methodological tools for the design and evaluation of the concept, and examines current trends in the fields of HCI and user interface design that contribute to the concept of intuitive use. Finally, the chapter introduces the concept of *image schema theory* and examines its suitability for addressing the needs of design for intuitive use.

2.1 THEORETICAL FOUNDATION OF INTUITION

The word *intuition* originates from the Latin word *intueri,* which means to look, gaze, or know from within. Intuition is an integral part of human nature; it is a part of the human experience. The definition of intuition—and its mechanism and attributes—has been the subject of much controversy in the past (Bastick, 1982; Boucavalas, 1997; Sinclair and Ashkanasy, 2005; Hodgkinson et al., 2008). Over the last few decades, several studies with converging views have emerged from the fields of education and learning (Simonton, 1980; Hogarth, 2001), decision-making (Klein, 1993; Kahneman and Fredrick, 2002), psychology (Bastick, 1982; Sinclair and Ashkanasy, 2005), and neuroscience (Damasio, 1994; Lieberman, 2000). Two main groups of researchers can be identified in these studies. The first group considers intuition as a processing method that utilises recognition as a mechanism for the retrieval of stored knowledge (Agor, 1986; Hammond et al., 1987; Simon, 1987; Klein, 1998; Hogarth, 2001; Miller and Ireland, 2005). These researchers consider intuition to be an experience-based phenomenon that is purely *cognitive* in nature. The second group regards *affect* as a component of the intuitive process (Epstein, 1998; Sadler-Smith, 2001; Kahneman, 2003; Sinclair and Ashkanasay, 2005). The affective element is the emotion that results from the interaction, and is part of the user’s experience (Park et al., 2013). In other words, affect-based researchers consider affect in conjunction with cognition as part of the mechanism of intuition. Previous studies have reported that attributes that constitute the concept of *intuition* include prior knowledge, subconscious processing, sudden awareness of cues, and experiencing of emotion. Studies have also reported lack of verbalisation, confidence in answers, expectation, and being very quick in decision-making (Klein, 1993; 1998, Wicken et al., 1998; Kahneman, 2003) to be parts of the intuition process.

Humans are naturally adventurous by nature, and as such they encounter various tools in their daily interactions. Over time, these encounters are stored in our long-term memory as an experience. When the user is faced with a similar situation, he or she utilise intuition as a means of scanning their long term-memory in order to identify the solution that best fits the current situation. In other words, intuition searches for a good match between the stored experience and the perceived stimuli.

Intuition is mostly triggered in a familiar domain (Nodding and Shores, 1984). This means that the richer the experience of the user, the more likely he or she will recognise the situation at hand, and the more frequent and available the mechanism of intuition will be utilised in making decisions. The subconscious mind finds a link between the new situation and various patterns of the stored past experiences. Rasmussen (1986, 1993) claims that this information (from a similar situation) is perceived from the environment as *signs*. Signs are cues that activate rules that have accumulated from past experiences of previous successful solutions.

These studies demonstrate that intuition is not magical, but rather relies on learned knowledge that has accumulated over the years, and that it is triggered by the mechanism of recognition.

2.1.1 Cognitive Processes

Although there is a general consensus that previous experience is the main attribute of intuition, divergent views exist on how that experience is stored and retrieved from long-term memory (Hammond et al., 1987; Simon, 1987; Epstein, 1994; Sinclair et al., 2002). As mentioned earlier, two main groups of researchers can be identified in previous studies. The first group attributes intuition in psychology to a processing that is purely cognitive. Humans process information stored in the long-term memory either consciously or subconsciously. Rasmussen (1986, 1993) made a distinction between conscious and subconscious processing in his information processing model. The conscious processor has a rather limited capacity and speed, and is sequential in handling data. The data handling relies on rational deduction and symbolic reasoning and requires attention, while the subconscious processor has amazing processing capabilities; it handles data in parallel and is effortless in processing information.

Many of the existing studies on intuition have employed dual processing models. Examples include Stanovich's systems 1 and 2 (Stanovich and West, 2000), Epstein's experiential and rational system (1998), Hammond's intuitive and analytic cognition (Hammond et al., 1987), Sloman's associative and rule-based system (1996; 2002), Evans's heuristic and analytical processes (2009), Lieberman's C-system and X-system (2000), and Klein's recognition prime and decision choice models (1998). Very few models, however, have fully accommodated the cognitive processes involved in intuition (Hammond et al., 1987; Rasmussen, 1993; Klein 1998; Wicken et al., 1998; Kahneman, 2003).

Significantly, the studies by Wicken and colleagues (Wicken et al., 1998) are consistent with Rasmussen's (1993) view on human behaviour and intuition. Rasmussen (1993) differentiates between three types of human behaviour: skill-based, rule-based, and knowledge-based. *Skill-based* behaviour represents performance during activities, after a statement of intention has taken place without conscious effort; it manifests itself as a smooth, automated, and highly inter-related pattern of behaviour. *Rule-based* behaviour typically is consciously controlled by a stored set of rules or procedures that may have been derived empirically during a previous occasion, communicated from other peoples' knowledge, or generated by conscious problem solving and planning. In *knowledge-based* behaviour, the goal is formulated explicitly, based on an analysis of the environment and the person's overall aims. Wicken et al. (1998), in their expanded information processing model, call rule-based behaviour 'intuitive processing', and claim that people interpret environmental cues using one of three levels: *automatic* (skill-based) processing, *intuitive* (rule-based) processing, and *analytical* (knowledge-based) processing. The processing strategies that people are likely to use depends on the specific job or other circumstances, their level of expertise, the amount of time they have to make the decision, and the amount of uncertainty involved (Blackler, 2006). In a real-world context, a person can operate at the skill-based (automatic), rule-based (intuitive), and knowledge-based (analytical) levels, and can switch between them, depending on his or her familiarity with a task.

Based on the analysis of these studies, intuitive processing is considered to be a partially automatic processing system that lies between automatic (skill-based behaviour) and analytical processing (knowledge-based behaviour).

2.1.2 Affective Processes

The role of affect in intuitive processing has been the subject of much debate. Several studies have suggested that emotions are stored with a person's previous experience, and are part of the retrieval process (Damasio, 1994; Epstein, 1998; Finucane et al., 2000; Slovic et al., 2002; Sinclair and Ashkanasy, 2005; Keller et al., 2006; Glockner and Witteman, 2010).

Glockner and Witteman (2010) attempt to clarify the ambiguity that exists between the two groups (cognitive and affect) by splitting intuition into four types, comprising associative, matching, accumulative, and constructive intuition. They further distinguish the various processes underlying the different types. According to their approach, affect plays no role in the retrieval of stored knowledge in associative intuition. In other words, associative intuition is similar to the position of the experience-based researchers. The mechanism underlying the associative intuition process is purely cognitive, and has no affective element. In the other types of intuition—the matching, accumulative, and constructive types—Glockner and Witteman claim that the affective and cognitive aspects are part of the intuitive process. These types of intuition are consistent with the position of the affect-based researchers. (For a similar analysis of the various roles that affect plays in the intuitive process, see Sinclair et al., 2002 and Sinclair and Ashkanasy, 2005.)

The *somatic marker theory* postulated by Damasio (1994) provides strong evidence of the role of affect in the intuitive process. He distinguishes between primary and secondary emotion, and calls the primary emotion ‘innate experience’. He claims that primary emotion does not describe the full range of emotional behaviour; according to his theory, secondary emotions are formed based on the association of the experienced situation to the primary emotion. To select a response, a person needs to pair a current situation with similar ones from the past that have led to the most advantageous outcomes. Somatic pairing is formed in early childhood, and is subsequently used throughout a person’s life. Associations with various markers vary from person to person, based on experience. Damasio further relates somatic markers to a conscious and unconscious process: ‘At the subconscious level, the explicit imagery related to an outcome would be generated, but instead of producing a perceptible body change, it could inhibit the regulatory neural circuits in the brain, which controls aversive or approach behaviour’ (1994). A negative option might be avoided altogether, and a positive one made more likely, by this covert mechanism, which Damasio suggests may be a part of intuition. This work accords with the ‘affect heuristic’ (Finucane et al., 2000; Slovic et al., 2002; Keller et al., 2006), which postulates that an ‘affect tag’ is stored with the previous experience, and that when a user is faced with making a decision, he or she will select the option with the most positive affect tags. Similarly, Sinclair’s exploratory study (Sinclair et al., 2002) on the relationship between intuition and affect indicates that positive emotional response is related to intuitive preference.

The somatic marker theory and the affect heuristic provide strong evidence that affect is an integral part of the intuitive processes. These studies have shown that positive or negative somatic markers or heuristic tags attached to a record of experience in one's memory could guide interaction either intuitively or analytically.

2.1.3 Discussion

This section has reviewed the theoretical foundation and process of intuition as a basis for utilising it in product use. The review has highlighted the following points:

(1) Intuition is attributed to a processing style that is based on past experience;

(2) Intuitive processing is considered a partially automatic processing that lies between automatic processing (skill-based behaviour) and analytical processing (knowledge-based behaviour);

(3) The mechanism of intuition relies on recognition or familiarity as a trigger for retrieving stored rules in the long-term memory;

(4) Intuition comprises both cognitive and affective elements; and

(5) Intuitive processes correlate with positive preference.

Having established the mechanism of intuition based on previous research, the next section will relate how the understanding is utilised in design for intuitive use.

2.2 DESIGN FOR INTUITIVE USE

This section reviews the current state-of-the-art methodological tools for the design and evaluation of intuitive use. The methodological approaches for exploring the concept of intuitive use have mostly come from two main research groups: the Australian and the intuitive use of user interface (IUUI) research groups. Most of the studies or approaches developed in this area align with these two research groups.

2.2.1 Previous Approaches for Exploring Intuitive Use

Several researchers have discussed the concept of intuitive use in the fields of HCI and design (Raskin, 1994; Cooper, 1995; Frank and Cushcieri, 1997; Lehikoinene and Roykkee, 2001; Vroubel et al., 2001; Rosson and Carrol, 2002; Dixon and O'Reilly, 2002 and Spool, 2005). None of these studies, however, have explained how the mechanism of intuition is related to product use.

The most comprehensive research on design for intuitive use was conducted by Blackler and her colleagues (Blackler et al., 2003a; 2003b). They reviewed literature on past work in HCI, design, and other theories that contribute to the concept of intuitive use. They described intuitive use as follows:

> *Intuitive use of products involves utilising knowledge gained through other experiences. Therefore, products that people use intuitively are those with features they have encountered before. Intuitive interaction is fast and generally non-conscious, so people may be unable to explain how they made decisions during intuitive interaction*. (Blackler et al., 2003a).

This description highlights five important attributes of intuitive use that can be utilised in the realm of HCI and design. These attributes are *prior knowledge*, *subconscious processing*, *familiarity*, *difficulty of being verbalised*, and *quickness*. Most of these attributes accord with previous studies of intuition in psychology (Hammond et al., 1987; Sinclair and Ashkanasy, 2005; Hodgkinson et al., 2008).

Blackler's team explored their definition by conducting a series of empirical studies examining the attributes of intuition (Blackler et al., 2003a; 2003b, 2010). These studies' findings reveal that prior experience of specific and general features of a product facilitate the intuitive use of that product. For example, the use of the 'stop' icon in a digital product such as a camera or a printer can be used in a new product, and the user will be able to relate with that icon. Based on these findings, Blackler and colleagues suggested three principles for creating intuitive interfaces: (1) use familiar features for well-known functions, (2) transfer familiar things from other domains, and (3) increase redundancy and internal consistency of function, appearance, and location with the interface. These principles have been utilised into the continuum of intuitive interaction (Blackler and Hurtienne, 2007). The three principles relate to the continuum of intuitive interaction in the following ways.

The first principle advocates designing interfaces using body reflectors, population stereotypes, and features from existing products in the same domain. The second principle suggests the use of metaphors and familiar features from other domains. The third principle recommends providing alternative ways of doing things, so that both novices and experts, and older and younger users, can use the same interface easily and efficiently. Keeping internal consistency allows users to apply the same knowledge and metaphors throughout the interface. These principles and the continuum of intuitive interactions have been developed into a conceptual tool for applying intuitive interactions (Blackler and Hurtienne, 2007). Recently, the tool was effectively used in two trial studies (Blackler et al., 2014). The results showed that the participants rated the products that had been designed with the conceptual tool higher in terms of their intuitive attributes than they rated the old version.

The research by Blackler and colleagues demonstrates that intuitive use is a function of the user's familiarity with similar features. In other words, a feature that is familiar to the user is likely to be used intuitively. Blackler et al. quantified 'familiarity' by using a technology familiarity scale. Their findings revealed that familiarity scores correlated with intuitive use, as measured by quicker task times and intuitive first use. The methods they used to compute familiarity—based on location, appearance, and the function of similar features used in the past—can be very laborious, however, especially when applied to a complex product. In addition, the way in which the researchers calculated the participants' familiarity with technology in these studies was also subjective.

The IUUI research group has also been prominent in conducting research exploring the concept of intuitive use. They have proposed the continuum of prior-knowledge as bases for exploring the concept. This approach suggests that the continuum of prior knowledge acquired before interaction with new products comes from a variety of sources (Hurtienne and Israel, 2007) including innate knowledge, sensorimotor skills, culture, expertise, and the use of tools. The continuum comprises prior knowledge acquired before interaction, arranged from bottom to top: the potential number of people who possess a particular type of knowledge in the continuum of knowledge decreases from the bottom to the top. In other words, the lower the level of knowledge in the continuum, the more widely available it is. The frequent encoding and retrieval from memory of the lower-level knowledge in the continuum leads to higher robustness of information processing. Therefore, applying knowledge to interface design from the low levels of the continuum increases the possibility of intuitive user interaction. Similarly to the previously mentioned definition, intuitive use is defined in this approach as 'the user's unconscious application of prior knowledge [which] leads to effective interaction' (Mohs et al., 2006). Intuitive interaction is measured in this approach using the International Organization for Standardization (ISO) usability standard, which employs effectiveness, efficiency, and satisfaction; *effectiveness* is related to perceived error rate and achievement of goals, *efficiency* is related to perceived effortlessness (cognitive effort), and *satisfaction* is related to attitudes about the use of the product. The status of affect in intuitive processing based on this research group is unclear.

In addition, Mohs et al. (2006) proposed seven principles—including suitability for the task, conformity with the user's expectations, self-descriptiveness, consistency, feedback, affordance, and gestalt laws—for design for intuitive use. All of these principles are relevant to the field of intuitive interaction. For example, *suitability* for the task involves presenting in the interface the relevant information for completing the task; placing unnecessary information in the interface reduces users' efficiency in the use of cognitive resources while completing the task. *Conformity* with the users' expectations involves using familiar design features and accepted conventions. Designers should use *self-descriptive* features that explain the product use through cues. *Consistency* involves following general principles in terms of interaction procedures and terminologies. *Feedback* provides a way to help users know what is happening, and to anticipate what to do next. Employing *gestalt laws* improves clarity and increases the chance of subconsciously using the product features. It should be mentioned that these principles are simply a checklist for helping designers organise their designs; there are no assurances of inducing intuitive usage in the product.

Further studies have focussed on using the sensorimotor level of knowledge in the continuum; this has resulted in the development of a database (ISCAT) of image schemas (Hurtienne and Israel, 2007), which is supported by a series of product studies. Image schemas are employed to analyse product features in terms of *effect strength*, which is estimated based on whether the identified image schema instances support, hinder, or are neutral to usability. This approach, however, is also subjective. Conducting an empirical study involving the observation of real interactions of actual users would have been more appropriate for this type of study.

Most of the other approaches developed to explore the concept of intuitive use predominantly emanate from the two main research groups mentioned earlier. Fischer et al. (2009) proposed an activation trigger schema (ATS) as a means of exploring intuitive interaction. This approach is built on the understanding of how a procedure learned in a given content can be transferred to an unfamiliar domain. According to this study, perception, interpretation, specification, and execution can be shortened when prior schemas are triggered. The proposed approach was demonstrated with two cognitive designed tasks involving novice users split into induction and perception groups. The task involved matching the interface of a prototype on-board computer with a function (inductive group) compared to a word (perception group), in order to examine which group facilitated schema induction and interacted with familiarity. Subsequent interactive performances with the system validated the induction effect of the procedure and its interaction with familiarity, known as the primary factor of intuitive use. Although the study claimed that the approach could be applied easily, especially for complex products, the procedure for knowledge transfer from the source to the target domain is unclear.

Research on intuition in a number of areas, including psychology, education, management, decision-making, cognitive engineering, and neuroscience, has identified seventeen attributes, and has developed a comprehensive framework for exploring intuitive interaction (O'Brien et al., 2010). O'Brien et al. also proposed a working definition of intuitive interaction: 'Interaction between human and high technology in a lenient learning environment that allows humans to use a combination of prior experience and feed forward methods to achieve their functional and abstract goals' (O'Brien et al., 2010). Unlike previous research that had focussed on functional goals, this definition focussed on both functional and abstract goals. There has been ongoing work in developing the conceptual framework into an analytical tool for measuring intuitive interaction. At the time of writing, there is no information about whether or not this tool has been empirically validated.

Spool's two conditions of intuitive interaction (2005) postulate that at least one of these conditions must be satisfied before intuitive interaction can occur. The first condition suggests that current knowledge (which is the amount of knowledge users have when they approach an interface) and the target knowledge (which is the knowledge they need to know in order to accomplish their objective) must be identical. The closer together the current and target knowledge are, the more intuitive the interaction will be. This condition emphasises the need to find a way of identifying the knowledge that users currently possess in order to design intuitively useable products. The second condition refers to a more common situation where there is a gap between the current knowledge and the target knowledge. For intuitive interaction to occur, the second condition expects users to be completely unaware that the design is helping them to bridge that gap. This condition necessitates creating an effortless way to bridge the gap between the current and target knowledge. The validity of these conditions has not yet been tested in empirical studies.

2.2.2 Discussion

This section has reviewed the current state-of-the-art methodological tools for exploring the concept of design for intuitive use. The review has highlighted the following points:

(1) There is consensus amongst researchers in the HCI and design fields that prior experience deployed in the area of familiarity is the key factor for design for intuitive use;
(2) Previous studies have predominantly employed a qualitative approach for exploring the concept of intuitive use;
(3) A methodology for determining if the evaluation of an interaction is intuitive or not in quantitative terms is currently unavailable. An approach for quantifying intuitive interaction would help designers to design products that are intuitively useable;
(4) There has been limited work on how the affective aspect of intuition is integrated into design and the evaluation of intuitive use. Most of the previous work has focussed on the cognitive use of previous knowledge. As a result, utilising the affective aspect of intuition in the design and evaluation of intuitive use would be beneficial.

The next section widens the search space for theories that contribute to design for intuitive use.

2.3 CURRENT TRENDS THAT SUPPORT INTUITIVE USE

This section considers current trends in HCI and user interface design (UID) that address the cognitive and the affective aspects of intuition; it examines the contributions and relationships of such theories to intuitive use. Although previous studies have identified and applied some theories and principles (Blackler and Hurtienne, 2007; Naumann et al., 2007; Mohs et al., 2007; O’ Brien et al., 2010), these principles have been limited in terms of providing appropriate guidance based on the attribute of intuition adopted in this thesis. As mentioned earlier, this study considers affective and cognitive attributes as part of the intuitive process.

2.3.1 Usability

Usability is defined as the extent to which a product can be used by a specific user to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use (ISO 9241 part 11, 1998). When users are confronted with the use of a tool, they creatively select the interaction style that fits their own understanding of the system, and their aims and situation. In other words, they develop a mental model of how the product should function. The usability of products can be improved by incorporating features that are beneficial in the context of use to aid the user in completing the task.

Some usability experts have worked in accordance with ISO standard (Nielson, 1993; Cakir, 2000; Kwahk and Han 2002; Ji et al., 2009). Nielson (1993) defines *usability* as a quality attribute that assesses how easy interfaces are to use. He claims that for a product to be labelled 'useable', it must be pleasant to use. According to his framework, the concept of usability is divided into five measurable attributes: learnability (ease of use of a product), efficiency (how quickly users can perform their task), memorability (ease of use of infrequent user), error (number of errors produced by users), and satisfaction (how pleasant is it to use the product). The analysis shows that Nielsen's five factors of measurement can be condensed into the three measurable attributes of the ISO. His usability measure has two similar components with the ISO standard for efficiency and satisfaction: error rate from his definition is in tandem with accuracy and completeness, which is called 'effectiveness' in the ISO standards.

Kwahk and Han (2002) have suggested a usability framework comprising three components: the interface feature of a product as design variable; the context variable and the usability measures as dependent variables. Their usability measures include both pragmatic (usability of the system) and hedonic (positive subjective feelings) quality. Jin et al., (2009), developed a usability evaluation model using quality function deployment applied to dishwasher. Over twenty usability dimension were applied to evaluate the dishwasher. Some of the usability dimensions, which includes consistency, familiarity and feedbacks are related to intuitive use.

Furthermore, some authors have attempted to inter-relate the concept of usability and intuitive use in their studies. Hurtienne (2011) reported a study involving human and ergonomics experts rating the relatedness of intuitive use to the seven dialogue principles of ISO 9241 on a scale of 1–5. As expected, conformity with users' expectation and self-descriptiveness were rated very high, with a mean score above 4. These two aspects are related to the past experience of the user, which is the primary factor of intuitive use.

Blackler (2006), in drawing conclusions on the relatedness of usability and intuitive use, posits 'therefore intuitive interaction is important for aspects of usability that relate to initial and occasional uses of products, easier to learn and provide more positive first time experience with things'. It can be inferred from her conclusion that ease of learning is related to the effectiveness factor, while a positive first-time experience is related to the satisfaction factor in usability.

Hurtienne (2011) conducted a comprehensive analysis linking the concept of usability to intuitive use. The researcher analysed ISO 9241 part 11 (Guidance on usability) based on the three usability factors of effectiveness, efficiency, and satisfaction and related each factor with their indicators. He concluded that for effectiveness (accuracy and completeness in actualising a goal), all the indicators are relevant for intuitive use. The efficiency factor (resources expended in actualising a goal) has two aspects: physical and mental resources. Intuitive use is only applicable to the effective use of cognitive resources, while the physical resources are not relevant for intuitive use. The satisfaction factor (attitude about the use of a product) has a positive indicator for intuitive use.

From the analysis of the definitions, both usability and intuitive use share similar characteristics in terms of their measurement criteria of effectiveness and satisfaction. The major difference is in efficiency measurement, which only maximises a singular aspect of the usability indicator of cognitive workloads, at the expense of physical workloads.

2.3.2 User Experience (UX)

'User experience' is defined as a person's perception and responses that result from the use or anticipated use of a product, system, or services (ISO 9241, 1998). The concept refers to all aspects of the interaction, including a person's behaviour, beliefs, preferences, and emotions. The concept of user experience encompasses both the affective and functional (cognitive) needs of the users (Hassenzahl and Tractinsky, 2006). While the functional needs refer to the usability of the product, the affective need is the emotion that occurs as a result of the interaction with the product, and it is part of the user experience (Zhou et al., 2010; Xu et al., 2011; Park et al., 2013). For the affective elements to be implemented, Hassenzahl and Tractinsky (2006) suggest that the needs of the user must be better understood, defined, and operationalised.

Forlizzi and Battarbee (2004) classified the existing frameworks for understanding user experience as product-centred, user-centred, and interaction-centred models. The product-centred frameworks (Alben, 1996; Jääskö and Mattelmäki, 2003) predominantly focus on the experience evoked by the product. They are mostly developed as guidelines to help designers to incorporate aspects that can evoke pleasurable experiences when designing the product. The user-centred frameworks (Mäkelä and Fulton, 2001; Hassenzahl, 2003) focus on the aspects of the user's behaviour that designers can incorporate into the design in order to facilitate the ease of use of the product. The interaction-centred frameworks (Forlizzi and Ford, 2000; Mäkelä and Mattelmäki, 2002; Overbeeke and Wensveen, 2003) focus on the experiences that the product evokes as a mediator between the designer and the user. Furthermore, Forlizzi and Battarbee (2004) have shown that the interaction-centred model is the most valuable according to their classification system, as it incorporates aspects of the product-centred and the user-centred frameworks for gaining insight into user experience.

Hekkert (2006) describes user experience as the entire set of effects that are elicited by the interaction between a user and a product, including the degree to which all senses are gratified (aesthetic experience), the meaning attached to a product (experience of meaning or usability), and the emotion that are elicited (emotional experience). People naturally use their cognitive, motor, and affective skills to interact with a product (Wensveen, 2005). The experience of meaning is linked to cognition; previous experience plays a great role in the association, interpretation, and retrieval of features from memory (Hekkert, 2006). A product that is designed with the user's previous experience in mind does what the user expects, with minimal cognitive effort and within the shortest possible time frame. Previous studies have used several usability measurement standards for evaluating user interfaces (Nielsen, 1993; Jordan, 1998, Park et al. 2013). The official usability measurement is based on effectiveness, efficiency, and satisfaction (ISO, 1998). The performance indicators commonly used are time on task for efficiency, accuracy for effectiveness, and preferences used for satisfaction measurement.

Furthermore, several researchers have identified the affective experience (emotion) as an integral component of user experience (Damasio, 1994; Finucane et al., 2000; Kahneman and Fredricks, 2002; Sinclair et al., 2002; Forlizzi and Battarbee, 2004; Hassenzahl and Tractinsky, 2006; Zhou et al., 2010; Xu et al., 2011). According to Damasio (1994), these emotions are attached to the records of the user experience, and form part of the retrieval process from long-term memory during interaction. In order to select a response, a person needs to pair the similar situation with the most advantageous somatic pairing. Consequently, affective responses are generated based on the appraisal of the system. Positive affective responses are likely to be used for a positive appraisal of the interaction and vice versa.

Several techniques have been developed to measure the affective state of the user; each has its strengths and weaknesses (Scherer, 2005). The most comprehensive multi-component model for measuring affect was developed by Scherer (1984; 2005). His model was developed to accommodate five dimensions of affective measurement, comprising cognitive appraisal, subjective feeling, physiological measurement, motor expression, and behavioural tendencies.

Subjective feelings can be assessed through the use of questionnaires, rating scales, checklists, and analysis of the verbal responses. Several tools have been developed for measuring the affective state based on subjective feelings. These include the affect grid (Russel et al., 1989), the Geneva Affect Label Coder (GALC) (Scherer, 2005), and dimensional emotional theory (Mehrabian, 1996). Most of the tools available for assessing subjective feelings are either based on a fixed or free response of the user. For example, in the affect grid, a form of fixed response tool assesses emotional state on a scale from 1–9 scale, including such measures as pleasure-displeasure and arousal-sleepiness. Users are asked to rate their emotional state by marking in one field of the matrix. Scherer (2005) has observed, however, that the priming effect of the fixed response is one of the greatest limitations of the fixed response tool. Scherer's (2005) proposed GALC is a free response tool that is sorted into a more limited number of emotional categories. The free response is based on the assumption that people are aware to some extent of their emotional state, and are able to describe their emotions (Mehrabian, 1995).

Other methods used for measuring the affective state of users include physiological measurement (Lang et al., 1993; Partala and Surakka, 2003) and motor measurement (Cacioppo et al., 1993; Schuller, 2006). For example, pupil radius can be used as an indication of the affective processing of the user (Partala and Surakka, 2003). These methods of measurement have been found to correlate with the affective state of the user.

2.3.3 Product Semantics

Semantics have been used in product design to represent the physical form of a product and its features. Krippendorff (1989) defines the term *product semantics* as 'the study of the symbolic qualities of man-made form in the cognitive and social context of their use and the application of the knowledge to industrial design'. Product feature design can be distinguished in terms of the implementation model, the represented model, and the mental model (Cooper and Reimann, 2003). The implementation model represents the idea of the designer of the system, while the represented model is the idea of the designer embodied in the product, which is the transmitting medium of the designer's intent. The user's model is what the user develops to understand the working of the system. Users do not have access to the designer's idea and, as such, their interpretations are purely based on previous experiences using the product or similar product features. The semantic-based approach to product design is primarily focussed on the meaning the user infers from the appearance of the features (You, 2007). The outward appearance of a product feature is capable of arousing users' cognitive response to the product. In other words, the clarity of the outward appearance of the product feature can greatly improve the interpretation that the users develop on how the product functions (Demirbilek and Sener, 2003). Therefore, the meaning or understanding of the product is improved if the designer employs similar conventions for representing the appearance of the product features. The understanding, based on the interpretation of the features by the user, is reflected in the affective responses they use in describing the interactions.

Burnette (1994) described product semantics as the capacity of a product to afford meaning through its form and use, and expressed dismay that enough had not been done to develop ways of establishing expressive intent in products. He identified seven aspects of product semantics that could be incorporated into design. Two of these aspects involve cognitive meaning, derived from the abstract association, and emotional meaning, associated with remembered experience (Burnette, 1994). Similarly, Griffin (1999 in Demirbilek and Sener, 2003) posited that two distinct processes are involved in interpreting the semantic content of unfamiliar products. The first is knowledge, based on the context, while the second is emotion-based. These two processes are interpreted based on the associations drawn from previous experiences. In other words, the appearance of a product can generate negative or positive emotional responses in the user based on the context. Users can benefit if the designer employs a product form that is consistent with what they are familiar with or have experienced in the past.

Crilly et al. (2004) proposed a five-stage model (Figure 2.1) to capture product design. The stages are modelled based on the assumption that products are vehicles for communicating the designer's intent. The five stages include source, transmitter, channel, receiver, and destination. The *source* and *transmitter* stages are analogous to the implemented and represented models in the research by Cooper and Reinmann (2003); these are related to the designer's idea being embodied in the product. The *channel* is the environment in which the interaction takes place. The *receiver* corresponds to the user's senses activated in decoding the message embodied in the product, and the *destination* represents the responses generated based on the decoded message. The response is divided into cognitive, affective, and behavioural (Crilly et al., 2004) responses. *Cognitive response* refers to the appraisal of the product based on the semantic interpretation of the product. Consequent upon the appraisal, *affective responses* are generated from the interaction; these are the user's feelings about the use of the product. This is evident in the affect-related words used in describing the interaction (Park et al., 2013).

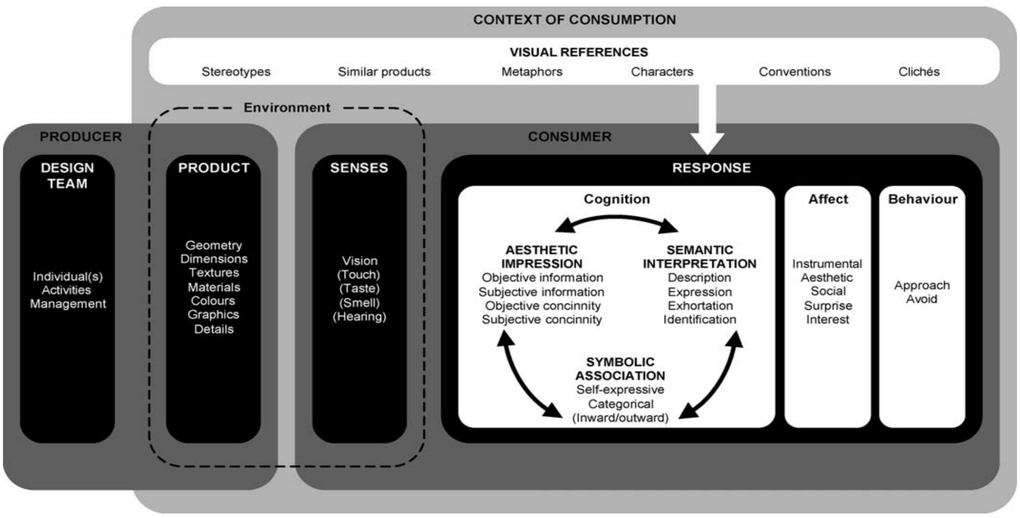


Fig 2.1: Framework for Design as a Process of Communication with Visual References (Crilly et al., 2004)

The ideal of a semantic approach to product design is relevant to intuitive use, as people base their understanding of the form of the product on past experience of similar products. The application of this theory increases the chances of users correctly interpreting its features. These outward appearances of the features trigger affective and cognitive responses on the part of the user based on past experience. Intuitive use has been found to be facilitated by designing a product feature with familiar appearance, placed in a familiar location and performing a familiar function (Blackler, 2006). A product that is consistent with what the user is familiar with in terms of functions is likely to be subconsciously used, thereby facilitating intuitive use.

2.3.4 Sentiment Analysis

Interaction with an interface is an experience that involves stimulus and response. The user's responses are based on the appraisal of the interface, which can be identified through the language and behaviour of the user. Humans use language to express their thoughts about an experience and to fulfil other needs. These experiences encompass the opinions held by a user. In this context, the analysis of these opinions is termed *sentiment analysis*. Sentiment analysis is the use of natural language processing to characterise opinions, sentiments, evaluations, appraisals, attitudes, and emotions towards entities such as products, services, organisations, individuals, issues, events, and other attributes in a source material (Liu, 2012).

The opinion expressed by different people on the use of a product can vary based on many factors, one of which is their familiarity with the product. Several theories, including Slovic's aforementioned 'affect heuristic' (Slovic et al., 2002) and Damasio's somatic marker theory (Damasio, 1994), support the fact that user experiences are stored in the long-term memory in conjunction with emotion. During the retrieval process, the emotion acts as a reminder for the previously stored information. In the context of user interaction with products, emotional responses are generated based on the 'affective tag' that has been attached to similar situations. The opinion expressed by the user can be used to identify the affective state of the user during interaction. In support of this theory, Sinclair et al. (2002) have found that a positive type of emotional response is correlated with intuitive preferences (Sinclair, 2002). A positive affective state activates intuitive processing, and vice versa (Damasio, 1994).

Several approaches have been developed to identify and classify sentiment. Cambria et al. (2013) classify the existing approaches as keyword spotting, lexical affinity, and statistical modelling. *Keyword spotting* is one of the most popular methods used in identifying sentiments in textual material. As the name implies, keyword spotting classifies texts based on the presence of affective words. The *lexical affinity* approach assigns an arbitrary word a probabilistic affinity for a particular emotion, while *statistical modelling* is based on machine learning applied to large data sources. All three approaches have their strengths and weaknesses. For example, keyword spotting is very accurate at sentence-level analysis, but has the shortcoming of ignoring words that are not necessarily 'affect' words, but that can be inferred to connote affective meaning. Lexical affinity, though also very accurate, is based on probability allocated to the affect word, which can be biased. The statistical model works very well with large data sets used as a knowledge base (Cambria et al., 2012).

In terms of product use, positive or negative opinions expressed by a person can be analysed in terms of the overall use of the product or at the level of particular product features (Liu, 2012). Clearly, the analysis of the overall use of the product lacks in-depth analysis of the product's design features. In contrast, the feature-level–based approach analyses the opinion based on the constituent parts or features of the product. Previous studies have found image schemas to be useful in analysing product features (Hurtienne and Israel, 2007; Asikhia et al., 2015). Therefore, the user's opinion on the use of image schemas during interaction can be classified based on these sentiments. Keyword spotting appears to work very well for the feature-level classification of the sentiment (Liu, 2012).

A large amount of work has been conducted to develop collections of affect-related words. Examples include the aforementioned GALC (Scherer, 2005) and the affect lexicon (Ortony et al., 1988). GALC is a free response tool that is structured into thirty-six different types of affect-related experiences (called 'categories') and their associated word stems. For example, 'disappointment' is a GALC category with twelve word stems: *come-down, disappoint, discontent, disenchant, disgruntle, disillusion, frustration, jilt, let-down, resign, sour*, and *thwart*.

2.3.5 Discussion

This section has reviewed the current trends that support the concept of design for intuitive use from the HCI and UID fields. The review has highlighted the following points:

(1) The concept of user experience and product semantics addresses the cognitive and affective aspects of users' interactions with a product, which makes it relevant for design for intuitive use;

(2) Intuitive use is considered to be an aspect of usability, with a focus on the efficient use of cognitive resources during interaction;

(3) Sentiment analysis is relevant to intuitive use in determining the affective state based on the affect-related words used in describing the interactions.

Having examined the current trends or theories in the HCI and design fields and their contributions to intuitive use, the next section will introduce the concept of image schema theory, the theory's theoretical foundation, and the suitability for addressing the needs of design for intuitive use.

2.4 IMAGE SCHEMA THEORY

2.4.1 Theoretical Underpinning

An *image schema* is a dynamic pattern of organism-environment interaction that gives understanding to experience emanating from human bodily interaction with the physical world (Johnson, 1987; 2012). For example,

> *The* verticality *schema provides a basis for our up-down orientation based on different experiences such as perceiving a tree, our felt sense of standing upright, the activity of climbing stairs, forming a mental image of a flagpole, measuring our children's height and experiencing of water rising in a bathtub*. (Johnson, 1987)

These various experiences represent the abstract structure of the *verticality* schema. Over time, an association relating these recurring experiences with the observed relationship is established in the user's subconscious. These associations are called 'metaphoric extensions' of the recurring experience. For example, the experience of water rising in a bathtub means that the more water is poured into the bathtub, the higher the level of water in the bathtub. Therefore, the *up-down* schema is used to provide an understanding, where more is up in the domain of quantity (Johnson, 1987). Such experiences acquired by the user over a long period of time can form interesting patterns that can subsequently be recruited for interaction with minimum cognitive effort, and in a quicker time frame (Lakoff and Johnson, 1980; Hurtienne and Blessing, 2007).

This image schema derived from sensory and perceptual experience as we interact with and move about in the world. For example, simple everyday experiences such as seeing object being inside or outside of a container, experiencing of water rising in a bathtub, or being at a centre or periphery of a spatial scene (Johnson, 1987; Hurtienne et al. 2015). The words used to describe these experiences act as a gateway to the structure the brain has composed to store the corresponding information.

In the above example, container, up-down, centre-periphery are all image schemas developed from recurring and similar interaction with the world and that have left traces in the brain. Another example is the abstract group of jars, rooms, cloths, glass etc., which collectively represents the image schema container. Each container image schema can be described as having an inside, outside, a boundary that allows movement in and out of the container (Hampe and lakoff, 2005). The container image schemas can be instantiated in language by the words in, out, enter, emerged, come out, come in etc. Similarly, the up-down image schema is grounded in our experiences of gravity coded in words like up, down, top, increase, decrease, rise, fall while centre-periphery captures the experience of humans being the perceptual centre of the world (Johnson, 1987). Other frequently used schemas include *near-far, big-small,* and *back-front*. Table 2.1 shows an overview of the standard inventory of image schemas as categorised by Langdon and Clarkson (2007).

Table 2.1: Image Schemas Classification (Langdon and Clarkson, 2007)

Group	**Image schemas**
Basic	*Substance, object*
Space	*Up-down, left-right, near-far, front-back, centre-periphery, contact, path, scale, Rotation*
Containment	*Container, in-out, content, full-empty, surface*
Multiplicity	*Merging, collection, splitting, part-whole, count-mass, linkage, matching*
Process	*Iteration, cycle*
Force	*Diversion, counterforce, restraint remover, resistance, attraction, compulsion, blockage, balance, momentum, enablement*
Attribute	*Heavy-light, dark-bright, big-small, warm-cold, strong-weak, straight*

While the inventory in Table 2.1 is far from exhaustive, the following list provides an idea of the range of image schemas that have been proposed so far in the literature (Lakoff and Johnson, 1980; Johnson 1987; Hampe, 2005; Hurtienne, 2011). The empirical notion of image schemas entails that image schemas listed in Table 2.1 are not mutually exclusive. Although, the grouping of image schemas suggests independent of one group from another. The relationships are manifold. Some image schemas depend on another, like restraint remover depends on blocking. Other entails each other. For example the boundary of a container can constitute a blockage preventing the content leaking from the container while some others depends on other image schemas in their instantiation (Hurtienne, 2011). The image schema scale depends on other image schema like up-down, left right or centre-periphery. Instantiation of the force image schemas always instantiates the path of a motion (Pena, 1999).

Depending on the author (e.g., Lakoff and Johnson, 1980; Johnson 1987; Hampe, 2005; Hurtienne, 2011), about forty-two image schemas—divided into eight groups, with over 250 metaphoric extensions—have been tested and validated in linguistic studies. These metaphoric extensions are correlations of sensorimotor experiences in the world. An image schema is meaningless without its metaphoric extension. Metaphoric extensions help to map the features from the source to the target domain via the *invariance hypothesis*, which states that metaphor only maps components of meaning of the source language that remain consistent in the target domain (Lakoff, 1990). This means that the aspect of the metaphoric extension that is mapped, and the aspect that is disregarded in the target domain, are determined by the hypothesis. For example, the 'love is a journey' metaphor preserves the structure of the *path* image schema, while the 'love is unity' metaphor preserves the structure of the *part-whole* image schema (Lakoff and Johnson, 1980; Hurtienne, 2011). The structural properties of the *path* image schema comprise a beginning, a goal, and a series of locations (Johnson, 1987). The structural elements of the *path* image schema are preserved in the metaphor relating love to a journey. A journey consists of a starting point, an ending point, and a path linking the starting point to the ending point. Similarly, the structural elements of the *part-whole* image schema comprise a whole, a part, and a configuration. The *part-whole* image schema is preserved in the metaphor relating love to unity. Unity represents wholeness, which is one of the structural elements of the *part-whole* image schema.

Several image schemas have been studied extensively in cognitive linguistics using verbal and nonverbal stimuli. Examples include *up-down* (Stanfield and Zwaan, 2001; Zwaan and Yaxley, 2003), *big-small* (Glover et al., 2004), *near-far* (Zwaan et al., 2004; Kaschak et al., 2006), *rotation* (Zwaan and Taylor, 2006), and *left-right* (Zwaan and Yaxley, 2003). These studies show that image schemas can be activated in audio, visual, and motor modalities, and that the responses of the participants are quicker if the image schemas activated are consistent with the stimuli presented, and slower if they are inconsistent.

There is evidence in the use of image schemas in other fields. For example, perceptual meaning analysis (PMA) accounts for the reality of image schemas in developmental psychology (Mandler, 1992; 2005). This evidence is mostly supported by work conducted by the following researchers: Mandler (1992, 2005); Baillargeon, Kotovsky, and Needham (1995); and Baillargeon and Wang (2002).

According to Mandler (1992; 2005), image schemas are the result of a process called 'perceptual meaning analysis' (PMA). The process involves extracting information from the perceptual information from the external world (stimuli) as a result of continuous attention. For example, a baby can identify blurring objects moving along a trajectory. This movement, which involves a start and an end point, instantiates the properties of the *path* image schema. The extracted meaning from the perceptual information represents the image schema. PMA can detect image schemas as early as three months in the early phases of child development (Mandler, 1992). Over time, these developed image schemas are progressively built upon in the course of one's life. For example, the concept of *support* is built on *contact* image schema, and *content* is dependent on the *container* image schema (Baillargeon, Kotovsky, and Needham, 1995). The status of image schemas as a form of prior knowledge is supported by PMA.

The findings in the previous studies conducted have a number of implications in the area of design for intuitive use. First, designers can take advantage of the multi-modal attributes (visual, audio, and motor) of image schemas to present interface features in different forms. Second, the invariance hypothesis provides the structure of the metaphoric mappings. According to Hurtienne (2011), the invariance hypothesis can help interface designers to focus on the relevant feature in user interface metaphors. In other words, the hypothesis provides an explanation of the relevant image schemas identified in the context of the task. Third, these studies indicate that image schemas could be used as an approach for design and evaluation of intuitive use of interfaces.

2.4.2 Image Schemas and Design for Intuitive Use

A limited number of studies have explored this potential in the fields of HCI and design, however, even though image schemas have been found to be very useful in describing interface features. For example, Kuhn and Frank (1991) applied image schema as a means of analysing the features of a camera. They described zooming as the transformation caused by changing the view distance, which instantiates the *near-far* image schema of the camera. In a similar study conducted by Hurtienne and Israel (2007), image schemas were used to classify interactions within a tangible interface, called a 'memory box'. The image schemas extracted from the taxonomy included *container, collection, matching, left-right,* and *up-down*. The study concluded that the taxonomy developed using image schemas is not contradictory, but rather complements other approaches. Other studies conducted using image schemas to analyse interface features include experiments with alarm clocks (Asikhia et al., 2015), Airbus 320 cockpits, and cash and ticketing machines (ISCAT, 2012).

In the same vein, Hurtienne et al. (2008) applied image schemas in a study investigating tangible user interfaces within the context of the four phases of the user-centred design process. Subsequently, they used this approach to redesign the invoice verification and posting system of a beverage distribution system. Their experiments showed that the redesign was rated higher than the original in terms of its usability, pleasantness, and attractiveness.

Other studies have been conducted using image schemas as a means for determining patterns of reasoning. For example, Britton et al. (2013) conducted an experiment to determine if mobile phones are designed as intuitively useable devices. The experiment involved a visual test with two schematics of Nokia and Sonny Eriksson systems, using a simplified button configuration. The study found that the most common image schemas for interaction, as indicated by the participants, were vertical and depth image schemas.

Another study, by Raubal and Worboys (1999), built a model using image schemas for way-finding tasks in a built environment. The image schemas used were extracted from the utterances of users while finding their way through a simulated airport. In a similar study, Manglo and Matlock (1999) analysed how people conduct searches of the World Wide Web. The empirical evidence from their interviews with beginners and experienced Web users revealed that experienced users of the Web were more likely to use image schemas than beginners were.

In an evaluation study conducted by Antle et al. (2011), *balance* schema and their contextual metaphor of balance in social justice were used to design the interactive model of a whole body interaction environment called a *springboard*. A springboard is a research instrument that allows empirical investigation of the details and benefits of embodied interaction in embedded computation systems. Participants were presented with three issues (food, security, and shelters), with each having two factors or metaphoric forces that had to be balanced to achieve a socially just solution. The tasks involved having the participants use the springboard to interact with each multimedia content set. The evaluation study revealed that participants had effective, efficient, and satisfying interactions with the interactive model.

Furthermore, image schemas have been used as a tool for design. Hurtienne et al. (2009) proposed a method to obtain population stereotypes with a special emphasis on physical-to-abstract mapping. Twenty-nine of these stereotypes were tested by applying the theories of conceptual metaphor and image schema. The emphasis was on the attribute group of image schemas because of their usefulness in tangible interaction. The Cohen kappa (k) was used as an index of metaphoric strength that was consistent with the metaphoric extensions. A k value above 0.6 was proposed in the study as a benchmark for recommending the image schemas to be used as a guideline for the design of tangible interfaces. Drawing heavily on Hurtienne's work, Macaranas et al. (2012) extended the research by testing and validating the spatial group of image schemas. Following the same approach, thirty metaphoric extensions were tested, using twenty participants. Twenty of the metaphoric extensions with a k value above 0.6 were recommended for user interface design.

Hurtienne (2011), conducted two studies to examine the inter rater reliability of image schemas used to describe user interface usage. Eleven participants were recruited in the first study in order to examine whether an image schema definition can easily be understood and related to user interface. They were asked to generate as many usage scenarios of a user interface that matched the presented sentences that contain different force image schemas. Thereafter, the usage scenario generated in the first study was presented to four experts familiar with image schema analysis in the second study. The experts were asked to reclassify the usage example generated in the first study. The procedure allowed estimating the inter-rater reliability of image schema classification both among the expert in the second study compared to the original classification in the first study. The overall interrater reliability was moderate with an overall kappa, k of 0.59. The study proposed using more than one rater to increase agreement. Furthermore, an inter rater reliability test was recommended as a pre-requisite for selecting the image schemas used in the design phase.

In a study conducted by Hurtienne and Langdon (2010), ten people were interviewed in their homes to determine how they kept cool during the summer and how they operated their heating and cooling systems. The analysis of their utterances revealed the use of fifty-one image schema metaphors. The researchers used the image schematic metaphors extracted to the specifications for the central thermostat. The evaluation of the standard heating/cooling device against the image schema–implemented design showed that the participants performed better (compared to the original design) when the image schemas were implemented.

An analysis of the previously conducted studies shows that image schemas can be identified and extracted from the point of view of a designer or user. The designer's perspective can be extracted by analysing the interface features via the task steps and product descriptions

(Hurtienne and Israel, 2007; Hurtienne et al., 2008; ISCAT, 2012; Asikhia et al., 2015). The image schemas employed by the users (the user's perspective) can be identified and extracted from direct observations (Hurtienne and Blessing, 2007; Britton et al., 2013,) and utterances (Raubal and Worboys, 1999; Maglio and Matlock, 1999; Hurtienne and Langdon, 2010). The image schemas identified and extracted in these studies have been used to improve intuitive interaction and redesign products.

A common limitation of all of these studies is the difficulty in extracting image schemas that are predominantly based on the personal expertise of the researcher involved. This could increase the likelihood of introducing subjective bias, thereby reducing the reliability of the assessment. Attempts have been made in the past to address the problem of the complex attributes of image schemas. For example, Hurtienne (2011) recommended an inter-rater reliability test to be conducted as a prerequisite for applying the theory to interface design. While the recommendation seems to work well for image schemas extracted using a single method, it is cumbersome for multiple methods.

2.4.3 Discussion

This section has reviewed the concept of image schemas, its theoretical foundation, and its suitability for addressing the needs of design for intuitive use. The review has highlighted the following points:

(1) The possibility of instantiating image schemas in visual, audio, and motor modalities makes it a promising approach for design and evaluation of intuitive use;

(2) The invariance hypothesis provides an explanation of the relevant metaphoric extension from the users' utterances that are mapped, and the aspects that are disregarded in the target domain;

(3) The evaluation approach adopted by previous studies has been mostly qualitative;

(4) Most of the previous studies have predominantly focussed on the cognitive aspect of intuitive use; only a limited amount of work has explored the affective aspect of intuition and integrated it into the evaluation of intuitive use;

(5) The use of personal expertise to identify and extract image schemas increases the likelihood of introducing subjective bias, thereby reducing reliability. A formal rule for extracting image schemas would greatly facilitate the reliability of the use of image schemas as a means for design and evaluation of intuitive use.

2.5 SUMMARY

This study has so far reviewed the relevant literature that addresses design for intuitive use, and has outlined the limitations of previous approaches. Some of the key limitations of the previous approaches include: (i) most of the previous approaches have been mainly limited to qualitative explorations of the concept; (ii) there has been limited work on the affective aspect of intuitive use. The approaches developed in previous studies have addressed the cognitive aspect of the intuitive use of products.

Finally, this chapter introduced the concept of *image schema theory*. Image schemas have been shown to have the potential to support human understanding about an experience, which is the primary factor of intuitive use. One of the key limitations of the use of image schema as an approach for the design and evaluation of intuitive use is the methods used for their extraction. Previous approaches were primarily dependent upon the expertise of the person conducting the research for extracting the identified image schemas. This, in turn, could reduce the reliability of the image schemas used for the assessment.

The findings and limitations from previous work will be used to provide a starting point for the work presented in Chapters 3–7.

CHAPTER 3

RESEARCH METHODOLOGY

This chapter describes the methodology adopted for the purpose of this study and addresses research gaps in two aspects. The first aspect involves developing a quantitative approach for evaluating intuitive interaction based on image schemas. The design plan for evaluating the first aspect involves two empirical studies: the first empirical study involves end-users of the products, while the second study involves experts in the field of HCI.

The second aspect involves developing an approach that addresses the affective aspect of intuitive use. This approach includes an algorithm for extracting image schemas, an ontology specifically developed for the needs of the study, and a sentiment analysis conducted on the use of the identified image schemas. A third empirical study, involving end-users, evaluates the second aspect of the research.

Furthermore, this chapter outlines the research instruments employed in the identification and extraction of the image schemas in the empirical study, both from the designer's and the users' perspective. Following that, the chapter discusses the methods used for the analysis and evaluation of the extracted image schemas.

3.1 INVESTIGATING DESIGNERS AND USERS RELATIONSHIP

This thesis aims to validate a new quantitative approach to evaluating intuitive interaction with products, which is based on comparison between designers' intentions and users' interactions with physical objects based on image schema.

Several models (Norman, 1988; Giard, 1989; Mono, 1997; Muller, 2001; Crilly et al., 2004; 2008) have described the relationship between the designer's intention and the user's interpretation. Most of the studies conducted have been based on the assumption that a product is considered to be a vehicle that communicates the designer's intent. In this context, the *designer's intent* refers to how a product is to be experienced, while the *user's interpretation* is based on how the products are actually perceived. Designers develop the products with the intent of eliciting certain interpretations. As users, the interpretation of the intent can be experienced in different ways, ranging from the experience of meaning (usability) and that of emotion (affect) (Hekkert, 2006; Desmet and Hekkert, 2007). The experience of meaning is linked to cognition; image schemas play an important role in the association, interpretation, and retrieval of features from memory (Hurtienne and Blessing, 2007; Maracanas et al, 2012; Britton et al., 2013). Furthermore, in terms of the experience of emotion, image schemas have the potential to support human understanding about an experience, and thus are likely to shape the words we used to describe these experiences (Kuhn, 2007, Hurtienne et al., 2008; Hurtienne et al, 2015).

This research proposes the use of image schemas as a means of representing the designer's intent (product description) and the user's interpretation based on their interaction with the product. Figure 3.1 shows the model proposed for comparing how designers intend a product to be expressed and how they are subsequently experienced by the users. The experience of meaning can be appreciated in terms of, for example, colour, shape, size, colour, texture, and 'icon' (for instance, an icon of a bell to denote an alarm setting on a clock). Image schemas have been used to represent different aspects of the product; for example, the *big-small* schema can capture the size, *attraction* and *bright-dark* can capture the colour, *rough-smooth* can capture the texture, while *matching* image schema can capture the icon. The experience of emotion can elicit different feelings (for example satisfaction, confusion, or surprise) that the use of the image schemas employ for the interaction.

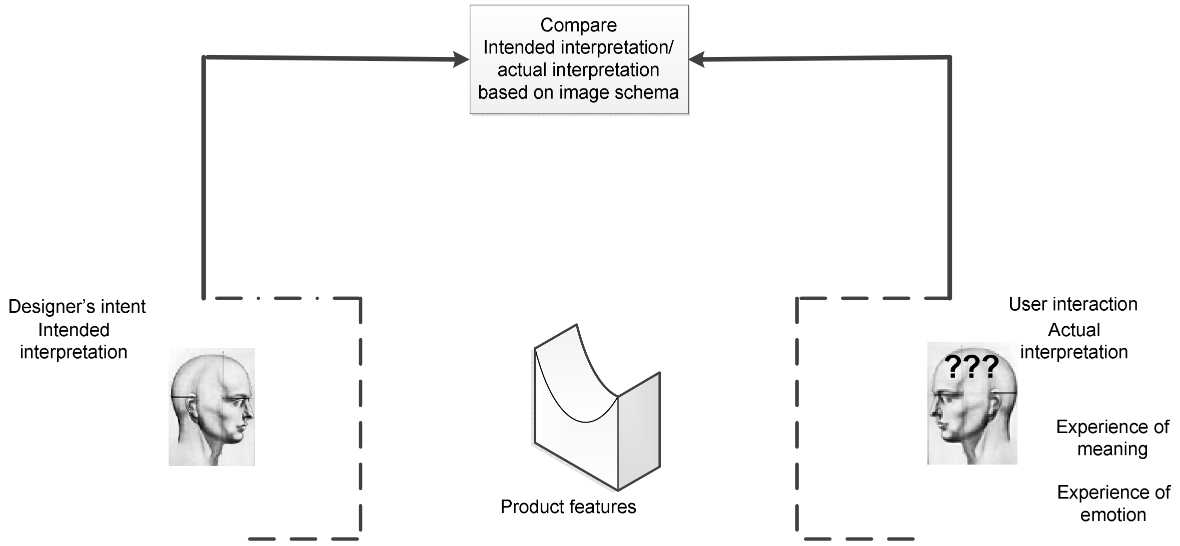


Figure 3.1 Model for Comparing Designer's Intent and User's Interpretation

3.2 STUDY DESIGN

The research plan for the current study consists of two phases. The first phase comprises a user study (study 1) and an independent evaluation study (study 2) that are conducted to illustrate how the quantitative approach is employed in evaluating intuitive use in products. The second phase involves a user study (study 3) that is designed to evaluate the approach developed for evaluating the affective aspect of intuitive interaction with products. The approach incorporates a novel algorithm and sentiment analysis in the evaluation process.

3.2.1: Pilot study

A pilot study was conducted to test the study design, examine preliminary data and to assess the feasibility of the full study. For the purpose, ten participants were recruited from Cardiff Metropolitan University to test different aspects of the study. The study took place at the product design and development research centre, Cardiff Metropolitan University, Cardiff.

The pilot study raised a number of key issues that fundamentally improved the study design of the main study. Three useful lessons were learned from the pilot study.

(i) The study design was improved by developing the research protocol for the full study. The protocol enabled the efficient sequencing of the various phases in the main study.

(ii) The five coding categories initially proposed was reduced to three after the pilot study. The breakdown of the initial proposed category includes: Identified correctly, consistent with the designer's intent, coded as 1: Identified correctly, inconsistent with the designer's intent, coded as 2: Unidentified, coded as 3: Unidentified initially, but recovered in the course of the task, coded as 4: unidentified, trial and error, coded as 5. Having examined the preliminary data from the pilot study, it was observed that the proposed coding was a bit cumbersome to apply. Consequently, the initial five coding categories proposed was reduced to three in the main study. The final coding used in the full study includes: Identified and correctly used, coded as 1, Identified but incorrectly used, coded as 2, Unidentified; trial and error used coded as 3. The final coding used in the main study was easy to apply.

(iii) Finally, the decision rules developed in the main study was conceptualised while examining the preliminary data from the pilot study. It was not initially obvious while developing the study design that there will be a conflict in terms of the coding of the multiple method proposed for extracting the image schemas.

3.2.2 Phase 1

Study 1:

The first empirical study is designed in order to identify the image schemas used to represent the designer's intent (analysis of the product feature) and the users' interpretations based on their interactions when completing a task. The image schemas, extracted both from the designer's intent and the users' interactions are analysed based on a coding system developed for the study. This study hypothesises that the closer the image schemas employed in designing the product are with the ones used in the interactions by the users, the more intuitive the interaction is, as measured by time on task, errors and cognitive effort. These variables have been used in previous studies as a means of measuring intuitive use of interfaces (Hurtienne and Blessing, 2007; Mohs et al., 2007; Naumann et al., 2007 and Hurtienne, 2011).

The studies conducted in ISCAT (2012) are the closest to the approach proposed in this current study. That study (in ISCAT) employed image schemas to analyse product features in terms of 'effect strength'. The effect strength of the image schemas identified in the product are estimated on a scale of 1–5, based on whether the identified image schemas supported, hindered, or are neutral to usability. The study used the analyst as a benchmark for estimating the effect strength without due recourse to the wide range of interpretation of how the product is actually perceived by the users, as this could have confounded the results of the analysis. A better approach may have been to observe the interaction of the actual users in an empirical study using multiple methods of gaining user insight (direct observation, the 'think aloud' protocol, the use of questionnaires and interviews). The interpretation of the user's interaction is thereafter used as a means of comparing the designer's intents.

To investigate this first aspect of the study, three multi-functional alarm clocks are used in the empirical study. They include one analogue and two digital alarm clocks with features similar to what is found in most common digital and analogue products. These products are chosen because they provided many interaction opportunities, based on a wide range of image schemas. A minimum of forty participants is proposed for the study based on similar previous studies conducted in the field.

A screening process is initially proposed to be used to select participants in the study. To be able to explore the concept of intuitive use, it was proper to explore the previous knowledge of the participants based on similar product used in the past. The concept of intuitive use is generally understood as an experience where a user immediately uses a new interface successfully based on his prior knowledge of other products (Blackler, 2003a). The pre-screening questionnaires contain six different products having some similar features with the product used in current study. For each of the product, the participants were asked to rate how often they used the product and how many of the features of the product they have used. Furthermore, it is also proposed that there is a balance in gender.

To this end, eighty screening questionnaires were sent to potential volunteers invited to the study. Only 42 participants returned the completed questionnaires. Consequently, the 42 participants that returned the completed questionnaires were therefore selected without screening based on availability. The participants are timed on completing a task while interacting with three different designs of alarm clocks. Each interaction is video-recorded and then analysed using Observer XT10 software. These observations are accompanied by a structured questionnaire and a short interview at the end of each session. Overall, 126 observations are conducted.

Study 2

The second study in the first phase involves an independent evaluation study. The study is designed to address two issues:

(1) To examine the inter-rater agreement of the image schemas identified to be relevant in the context of the task in study 1. The result of the study is used as a basis for selecting the image schemas used in the analysis phase;

(2) To compare the accuracy of the image schemas extracted by the developed algorithm for extracting image schemas from the transcribed utterances of the user (Chapter 6).

Two independent evaluators with experience in image schema analysis are given the task of extracting image schemas for the same task in the first study. Both evaluators are experts in product and interaction design, respectively. They are provided with the data used in the first study. The data include a transcript from the participants' interaction data (think aloud) and the task step and the product descriptions from the manuals. The three products used in the study are also displayed. They were asked to extract image schemas from the sets of data. The independent evaluators worked together and agreed on the image schemas assumed to be relevant for the task. Thereafter, an inter-rater agreement test is conducted using the Cohen kappa, *k*. Inter-rater agreement measures the degree of agreement between image schemas identified by the evaluators as relevant for the task. This statistical approach increases the reliability of the image schemas used in the analysis. The statistical tool is chosen for the test as it gives conservative results by taking into consideration the amount of agreement that could be expected to occur by chance. A *k* value of above 0.6 is proposed as a benchmark for selecting the image schemas used in the analysis phase. This value (0.6) is chosen partly because it represents a popular minimum benchmark agreement (Landis and Koch, 1977; Altmen, 1991) and also is consistent with previously conducted studies (Hurtienne et al., 2009, Macaranas, 2012).

3.2.3 Phase 2

Study 3

The third study is designed to evaluate the approach developed for evaluating the affective aspect of intuitive interaction with products. The affective elements are identified from the verbal responses of the participants based on the sentiments expressed while completing the task. The study uses the keyword-spotting as an approach for identifying the affective state of the users based on the sentiments used to describe the image schemas employed for the interaction. This approach works very well at the feature-level-description (Liu, 2012). The affective words identified (based on the free response of the participants) is characterised using GALC. This free response tool is chosen based on the assumption that most people are to some extent aware of their emotional state and are able to describe their emotions (Mehrabian, 2005).

Furthermore, the pupil radius measurement is proposed in the current study as a converging source of identifying the affective state. This physiological measurement has been found to correlate with the affective state of the user (Lang et al., 1993; Partala and Surakka, 2003).

The same approach used in study 1 is employed in recruiting participants in the third study. Forty six participants returned the screening questionnaires. These number include the forty participants that participated in the first study. For consistency, the forty volunteers that participated in both study was used in the analysis phase in study 3. . The Participants are timed and observed while completing a set task with two digital alarm clocks; all interactions are video recorded.

3.3 DATA COLLECTION METHODS

The multiple data collection methods used in this study are split into two. The first part comprises data collected from the user interactions. The current study adopts the use of direct observation, the 'think aloud' protocol, interview, and the use of questionnaires as a means for gaining user insight during interaction. Users' interpretation of a product feature can be complex; hence, using multiple means of gaining users' insights can increase the chances of capturing every aspect of the interaction.

The second part comprises the data collected from the designer's perspective. This involves the analysis of the product based on the task steps and product descriptions from the product documentation. This is used as a proxy to represent the designers' intent. This method is used for gaining insight into the designers' intent in the current study, based on the assumption that a product is considered as a vehicle that communicates the designer's intent (Miller, 2001; Cooper and Reimann, 2003; Crilly et al, 2004; 2008).

3.3.1 Direct Observation

Direct observation is a valuable method for collecting evaluation information. This method is considered to have high ecological validity, in that it monitors product usage in settings that are close to actual usage (Pershing et al., 2006). In addition, it provides access to data from the user, rather than depending on information from a self-report. This study uses on-the-spot data collection in conjunction with video recording of the interactions to produce greater insight into the observations. Because observers are not allowed to interfere in the interactions with the products in this method, there may be hidden details that the observers may not be able to interpret. To address this issue, this study uses direct observation in conjunction with other evaluation methods to capture the unobservable information. Furthermore, to reduce the pressure of the observer effect and the element of anxiety, participants in the study are spoken with before the study, to encourage them to be relaxed and to assure them that it is the product that is being tested, and not the participants.

During the study, participants are directly observed while interacting with the products, and their behaviour is recorded. An interaction task flow model, consisting of a sequence of subtasks, is developed for the tasks based on the product documentation. The task flow model helps to locate the tasks of the users and identifies every step they make. The image schemas used in each subtask are then identified and extracted from the recorded video observations of the users' actions.

3.3.2 Verbal Protocols

A *verbal protocol* is the recorded thought of users during or immediately after they have completed a task; protocol delivered while completing a task is referred to as *concurrent protocol*, and if it is delivered after the task, it is referred to as *retrospective protocol*. This method of data collection helps researchers to understand the thoughts of the users while interacting with a product. Because information accessible to people decays after a few milliseconds, this study adopts the concurrent verbal protocol, as a result of people forgetting relevant information while reporting retrospectively.

The use of protocols is helpful for gaining knowledge about the cognitive process of users' actions (Schooler, 2002; Blackler, 2006). Cognitive processes are not directly manifested in protocols; they have to be inferred. For example, verbalisation (or lack of it) is often associated with thoughts that are accessible to conscious and subconscious processing (Hammond et al., 1987; Schooler, 2002). The intuitive process depends on stored rules triggered by recognition to retrieve previously stored information. The intuitive process thus lies between fully unconscious and conscious processing. Blackler et al. (2006) positioned intuitive processing as lacking the details of logical thinking steps, while delivering concurrent verbal protocols.

During this study, participants are encouraged to verbalise their thoughts while interacting with the product. Although the protocol method has its own limitations in terms of users occasionally becoming silent during interaction, these effects are minimised by not pushing for protocols except when the users are absolutely silent while completing the task; in these cases, the participants are reminded to say their thoughts out loud. The utterances are recorded and then transcribed; the image schemas are extracted from the transcriptions.

3.3.3 Questionnaires

The use of questionnaires can be a useful way of extracting the right information from participants. The questionnaire used in this study comprised a combination of rating scale questions and open-ended questions. The first part, which involves open-ended questions, comprises of relevant research questions targeted to explore the users' interactions with the product. The second part, the subjective rating scale, is designed to measure user cognitive ratings for the completion of the task.

The questionnaires are presented to the users upon the completion of the task. The first part of the questionnaire contains three questions that targeted users' prior experience, and how this useful knowledge is transferred to this new domain. The main emphasis is on the description of the individual steps, as well as the features used for the completion of the task. The questions are structured in such a way that participants are given the opportunity to express all that they knew about the task without restriction. The second part of the questionnaire captures the subconscious aspect of the interactions. Participants rated their cognitive effort on a 5-point Likert scale. The participants' satisfaction rating is also recorded. The cognitive aspect is used as a means of evaluating the mental effort expended for the completion of a task. An intuitive process maximises the efficient use of cognitive resources during interactions (Hurtienne, 2011, Mohs et al., 2006, Blackler et al., 2010). The responses are collated and transcribed; the image schemas are extracted from the transcriptions.

3.3.4 Interview

The *interview method* of data collection primarily extracts data orally from users. The use of the interview helps to investigate issues in depth. This is done in order to extract relevant information that may not be captured by the other methods. This study adopts a structured approach for interviewing participants in order to aid consistency and to allow for the comparison of extracted information.

Participants are interviewed at the end of the completion of the tasks in order to yield more information about the study design. The interviews focus on three main aspects in the study: awareness of cues, the confidence level of the participants while completing the tasks, and their expectations about the use of the product. The interviews are recorded and then transcribed; the image schemas are extracted from the transcriptions.

3.3.5 Product Documentation

The *product documentation method* uses the interface description and task steps via the product documentation as a source for the data collection. Products can be seen as vehicles that convey the designer's idea (Norman, 1993; Cooper and Rieman, 1995; Crilly et al., 2004; 2008). This method of data collection is thus frequently used as a proxy for the designer's intent. Several studies have used this method to identify and extract image schemas (Hurtienne and Israel, 2007; ISCAT, 2012; Asikhia et al., 2015). The interface description comprises the appearance of the interface (shape, size, colour, and icon) and its arrangement (the spatial location of the interface features), while the function describes its use. Intuitive use is facilitated by designing an interface using a familiar appearance that is placed in a familiar location and that performs a familiar function (Blackler, 2006).

3.4 DATA ANALYSIS

The data analysis in the current study is divided into two phases. The first phase involves the analysis of the performance data of the participants using Observer XT10 software. Observer software is a manual for recording, collecting, managing, and analysing observation data (Noldus, 2010). The observer software is used to process time spent on tasks and the number of errors made by the participants. As was mentioned earlier, the cognitive effort expended for completing a task is processed from the structured questionnaires used in the study.

The second aspect of the analysis involves the extracted image schemas, both from the designer's and the users' perspectives. The analysis involves comparing the image schemas envisaged for the completion of the task from the designer's perspective with the image schemas employed for the completion of the task by the users. The analysis is conducted based on a coding category developed for the comparison.

The coding scheme developed for the comparison is divided into three categories. The first category involves image schemas that are correctly identified and used by the participants in accordance with the designer's intent. The second coding category involves image schemas that are correctly identified, but their use does not correspond with the designer's intent. The third coding scheme comprises image schemas that are unidentified during the study, but are completed through trial and error. This also includes image schemas that are identified by the participants, but are not represented in the design.

Following this, the evaluation of the analysed image schemas in the previous phase is conducted. This is based on the image schemas that are correctly identified by the participants in accordance with the designer's intent. The image schemas that fall in this category are then averaged over the image schemas represented in the design for the completion of the task.

3.5 SUMMARY

This chapter has described the methodology proposed for evaluating intuitive interactions in products. The approach involves extracting image schemas from the designer's and users' perspectives, with the aim of comparing their similarity. The study uses the image schemas extracted from the designer's intent as a benchmark for comparing image schemas used by the participants. The analysis is based on the degree of match using a coding system developed for the comparison. The degree of match (known as quantification, or 'Q' in this study) is used as a measure of intuitive interaction. The methodology described in this chapter is applied in Chapters 4–7.

CHAPTER 4

CONCEPTUAL FRAMEWORK FOR EVALUATING INTUITIVE INTERACTIONS

This chapter introduces the proposed conceptual framework for evaluating intuitive interactions based on image schemas. The framework was developed based on the literature conducted on the use of image schemas in the fields of HCI and design. Since most of the frameworks available in previous studies are predominantly qualitative, the proposed framework addresses the quantitative and qualitative evaluation of intuitive use in products. The quantitative aspect is based on evaluating the degree of match—known in this study as quantification, or 'Q'—between the designer's intent and the user's interactions, both expressed through image schemas. The qualitative aspect is interpreted and later used to improve the intuitive use of the product. The value of the proposed framework is in the provision of measurable outputs for evaluating intuitive interactions, and for identifying potential design flaws.

The framework comprises four phases (Figure 4.1): goal identification, image schema extraction, image schema analysis, and image schema assessment. The four phases are introduced below.

4.1 GOAL IDENTIFICATION

The process begins with identifying a functional goal (e.g., completing a specific task involving interaction with a product). The task is set by the evaluator, who then explored the possible paths for actualising the task that could be followed. The task is broken down into a sequence of subtasks. For each of the subtasks, the knowledge required to complete the subtask is identified based on the product documentation. This information represents the knowledge required to complete the subtask based on the designer's perspective.

During interaction, the knowledge actually used by the participants in completing the subtasks is identified by direct observation, think aloud protocol, questionnaires, and interviews. This is what the users developed to explain the execution of the tasks; this knowledge represents the user model.

4.2 IMAGE SCHEMA EXTRACTION

This phase involves extracting the relevant image schemas that correspond to the designer's intent (when designing a product) and user's interactions with a product (when completing a task).

The designer's intent represents the knowledge required to execute the goal. The framework uses two complementary sources of information for representing the designer's intent: the task steps and the descriptions of the product features. Both are extracted from the product documentation and then transcribed into image schemas by the experimenter. The product manual acted as a proxy for the designer's intent.

For the user's model, the proposed framework uses a variety of complementary sources to identify the knowledge employed by the user when interacting with a product. These include direct observations, think aloud protocols, questionnaires and interviews.

(i) ***Direct observation*.** Participants are directly observed while interacting with the product. An interaction task flow model consisting of a sequence of subtasks is developed for the tasks based on the product documentation. The task flow model helped to locate the task of the users and identified every step they made. The image schemas used in the task are extracted from the recorded video observation of the users' interactions with the product.

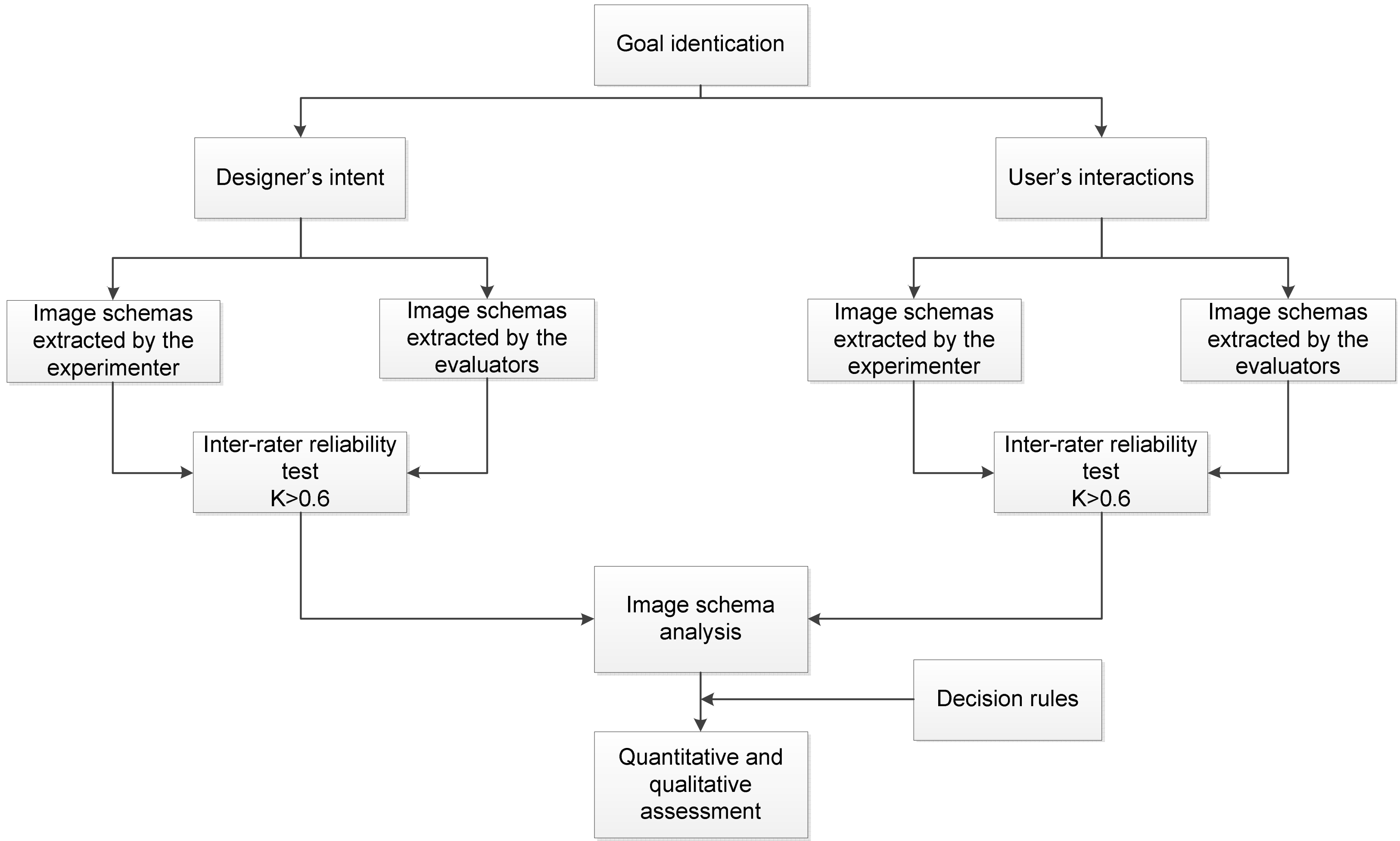


Figure 4.1: Conceptual Framework for Evaluating Intuitive Interaction

(ii) ***Think aloud protocol.*** This is a method that helps researchers to understand the thoughts of users while they are interacting with a product. The participants are encouraged to verbalise their thoughts. In think aloud protocol, the intuitive process is apparent by the absence of detailed and logical thinking steps (Blackler, 2006). The users' utterances are recorded and then transcribed, from which the image schemas are extracted for this study.

(iii) ***Questionnaire*****.** The questionnaires consist of a series of relevant research questions and subjective rating scale questions, designed to measure users' cognitive effort and satisfaction with the product. The responses to these questions are transcribed, and the image schemas are extracted from the answers.

(iv) ***Interview***. Participants are interviewed at the end of the task in order to elicit the information not captured by the other methods. The interviews followed a structured approach. The responses from the interviews are also transcribed, and the image schemas are extracted from the interviews.

The four methods adopted in the proposed approach are complementary, and allowed data extraction from multiple sources. An image schema is identified at the subtask level by one or more of the methods suggested above.

An inter-rater-reliability study is then conducted on the identified image schemas from the previous phase. This is conducted in order to examine the reliability of the image schemas identified in the previous phase. *Inter-rater reliability* measures the degree of agreement between image schemas identified by the evaluators. Independent evaluators with experience in image schema analysis are given the task of extracting the relevant image schemas for the same task in the study, both from the designer's intent and the users' interactions. The results of the study are used as a basis for selecting the image schemas used in the analysis phase.

4.3 IMAGE SCHEMAS ANALYSIS

This phase involves comparing similarities and differences between the image schemas corresponding to the designer's intent and user interaction, as extracted in the previous phase. The comparison uses a coding scheme comprising three categories.

The first category involves image schemas that are correctly identified and used by the participants in accordance with the designer's intent. In this category, there is a high degree of match between the designer's intent and the users' interpretation. Intuitive use is facilitated by a match between the user's interpretation, represented by the interactions, and the designer's intent, represented in the interface (Hurtienne, 2011). Therefore, as the schemas represent a subconscious form of human knowledge, this first category indicates that the more image schemas are correctly identified by a user during an interaction, the higher the chances of intuitive use of the product.

The second coding category involves image schemas that are correctly identified, but their use does not correspond with the designer's intent: there is a mismatch between the image schemas represented in the design (the designer's intent) and the image schemas used in implementing the interactions (the users' interpretation). This mismatch activates a swing from subconscious to analytical processing modes. Image schemas that are allocated to the second category have a greater likelihood of being used analytically, resulting in a greater use of mental effort, more errors, and longer task completion times.

The third coding category comprises image schemas that are unidentified during the study, but that are completed through trial and error. This category also includes image schemas that are identified by the participants, but are not represented in the design.

Table 4.1: Coding of the Three Categories

Categories	Description	Code
Identified and correctly used	This category includes image schemas that are correctly identified and used by the participants during the study in accordance with the designer's intent. For example, if a task involves the use of an *up-down* image schema as prescribed by the product manual, and the participants correctly identified its use during the interaction, the interaction is coded as Category 1: *identified and correctly used.*	1
Identified but incorrectly used	This category includes image schemas that are correctly identified, but their use does not correspond with the designer's intent during the interaction. For example, '*I thought the up and down button is to increase and decrease the time, but it is not working like that here'.*	2
Unidentified; trial and error used	The third category corresponds to *unidentified* image schemas during the study. This also includes cases where the tasks are completed through multiple attempts (trial and error). For example, '*I don't know what this button stands for; I am just trying it out'*.	3

The image schemas extracted in the previous phase by the four methods are categorised using the descriptions shown in Table 4.1. For each of the four methods used in extracting the identified image schemas in the study (direct observation, think aloud, questionnaires, and interviews), there are three possible categories. This means an image could appear as correctly identified, coded as 1; incorrectly identified, coded as 2; or found through trial and error, coded as 3. As a result, the combination of the four methods used for extracting image schemas in the study, with each appearing in any of the three categories, presents eighty-one (81) possible case scenarios.

Table 4.2 shows nine out of the eighty-one possible case scenarios of image schemas extracted from the four methods. (See Appendix A for all of the eighty-one possible case scenarios in the study.) For example, '1111' represents an image schema that is correctly identified by direct observation, think aloud, questionnaires, and interviews. The identification of the image schema in this example appears homogenous in the four methods used in extracting the image schema.

Table 4.2: Combination of the Methods Used for Extracting Image Schemas in the Study

Interview 1 / Questionnaire 1		Think aloud 1	Think aloud 2	Think aloud 3
Direct observation	**1**	1111	1211	1311
	2	2111	2211	2311
	3	3111	3211	3311

There are cases where conflicts exist in terms of the categories of the four methods, such as when an image schema appears in more than one category at the same time. This can create problems when deciding which image schema is relevant based on the method used for the extraction. For example, '1211' represents an image schema that is correctly identified by direct observation, questionnaires, and interviews, but incorrectly identified by the think aloud method. In such cases, the direct observation method is prioritised over the other three methods. This decision is based on empirical evidence collected in 252 observations involving 42 participants completing two set tasks with three different alarm clocks. Figure 4.2 shows the percentages of the image schemas identified by the four methods in accordance with the type of use (correctly, incorrectly, and trial and error) by all the participants in the study. It was observed across the three products used in the study that direct observation contributed significantly, with a mean percentage of 84.31 percent on a baseline of 100, followed by think aloud at 58.4 percent. The questionnaire (47.05 percent) and interview (46.35 percent) contributed less to identifying the type of use.

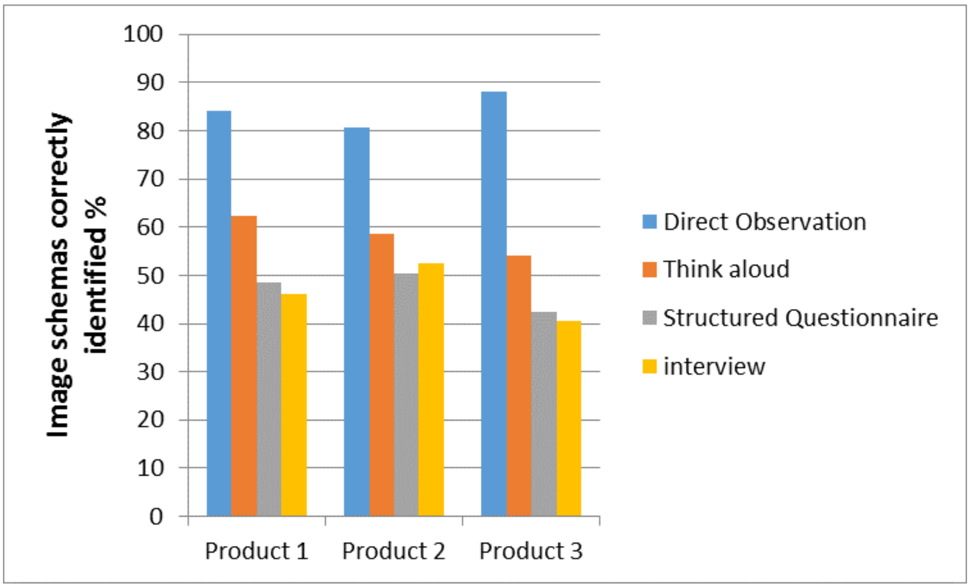


Figure 4.2: Chart Showing Identification Rates of the Methods Used for Extracting Image Schemas

Consequently, a set of decision rules was developed to resolve any conflicts stemming from the coding of the methods adopted in the study. The rules are listed below.

(1) If an image schema is identified by direct observation as being correctly used, then report the image schema as ‘correctly used’;

(2) If an image schema is identified by direct observation as being incorrectly used, then report the image schema as ‘incorrectly used’;

(3) If an image schema is unidentified (trial and error) by direct observation, but is identified by any of the three methods as being correctly used, then report the image schema as ‘correctly used’;

(4) If an image schema is unidentified (trial and error) by direct observation, but is identified by any of the three methods as being incorrectly used, then report the image schema as ‘incorrectly used’;

(5) If an image schema is unidentified by the four methods and is used by trial and error, then report the image schema as ‘used by trial and error’.

For example, if in a particular subtask the *matching* image schema is identified as correctly used by direct observation, incorrectly used by think aloud, and as trial and error by both interview and questionnaire, it is reported as being correctly used in the subtask, based on the first decision rule.

Table 4.3 shows the decision rules applied to a subtask that involves the use of the *matching* image schema based on the four methods. Image schemas identified as being correctly used are coded with the number 1, those identified as incorrectly used are coded as 2, while unidentified trial and error uses are coded as 3.

Table 4.3: *Matching* Image Schema Extracted from the Four Methods

Participants	Direct observation	Think aloud	Structured questionnaire	Interview	Decision
1	2	2	2	3	2:rule2
2	2	2	2	3	2:rule2
3	1	1	1	3	1:rule1
4	3	3	1	3	1:rule3
5	2	2	2	3	2:rule2
6	2	2	1	3	2:rule2
7	1	1	1	3	1:rule1
8	2	2	2	3	2:rule2
9	3	3	1	3	1:rule3
10	2	3	2	3	2:rule2
11	2	3	2	3	2:rule2
12	1	1	2	3	1:rule1
13	3	3	3	3	3:rule5
14	3	3	3	3	3:rule5
15	2	2	2	1	2:rule2
16	3	3	3	3	3:rule5
17	3	3	3	3	3:rule5
18	2	2	1	3	2:rule2
19	2	3	2	1	2:rule2
20	2	1	1	3	2:rule2
21	2	1	1	3	2:rule2
22	1	1	2	3	1:rule1
23	2	1	1	3	2:rule2
24	2	3	1	3	2:rule2
25	2	2	2	3	2:rule2
26	1	1	1	3	1:rule1
27	2	2	2	3	2:rule2
28	2	3	1	3	2:rule2
29	3	3	1	3	1:rule3
30	2	1	1	1	2:rule2
31	2	3	1	1	2:rule2

32	3	3	1	3	1:rule3
33	2	1	1	3	2:rule2
34	2	2	1	3	2:rule2
35	1	1	1	3	1:rule1
36	2	2	2	3	2:rule2
37	2	1	1	3	2:rule2
38	2	2	1	1	2:rule2
39	1	1	1	3	1:rule1
40	2	2	1	3	2:rule2
41	2	2	1	3	2:rule2
42	3	3	1	3	1:rule3

4.4 IMAGE SCHEMA ASSESSMENT

The proposed framework adopts quantitative and qualitative assessment techniques for evaluating intuitive interaction. This stage assesses the aforementioned code attributions (categories) both quantitatively and qualitatively.

(i) *Quantitative assessment*. For each extracted image schema, the percentage of participants that fall into Category 1 is calculated. These percentages are then averaged over all image schemas. This is calculated as the ratio of the sum of the percentages of times each particular identified image schema was used correctly by the participants over the number of image schemas represented in the design for the completion of the task. This is computed using the following equation:

$$Q = \frac{\sum_{i=1}^{m} n_i / p}{m} \qquad (4.1)$$

Where Q is quantification of intuitive interaction, n_i is the number of times i-th image schema is used correctly by the participants, p is the number of participants, and m is the number of image schemas represented in the design for the completion of the task.

For example, suppose two image schemas, *path* and *compulsion*, are employed in a particular subtask, and the observations show that these two image schemas are used correctly by the participants in 33 percent and 45 percent (respectively) of all instances. As a result, the quantification is computed as follows:

Number of times the *path* image schema was used correctly: n_i/p=33%

Number of times the *compulsion* image schema was used correctly: n_i/p=45%

Number of image schemas represented in the design=2

Using eqn. 4.1, $Q = \frac{\sum_{i=1}^{m} n_i/p}{m}$

$$Q = \frac{33\% + 45\%}{2} = 39\%$$

This 'Q' value represents the degree of match between the designer's intent and the users' interaction with the product for this subtask. The larger the degree of match, the greater the likelihood that the image schemas employed for the completion of the subtask were used intuitively.

(ii) *Qualitative assessment*. The image schemas that appear in Categories 2 and 3 are qualitatively interpreted and translated into recommendations for improving the design.

4.5 SUMMARY

This chapter has described the conceptual framework proposed for evaluating intuitive interaction based on image schema. In addition, it has described a technique for identifying and extracting image schemas from multiple methods that was developed as part of the framework. This technique was developed from a series of observations on the empirical studies conducted. It (the technique) was used as a basis for deciding which image schema was selected and used for the analysis. The value of the conceptual framework is in the provision of a measurable output of intuitive interactions.

Qualitative evaluation helps in capturing interaction difficulties and identifying potential design flaws. The assessment was generated from the participants who employed the image schemas that appeared in Categories 2 and 3. These image schemas have a greater likelihood of being used analytically, resulting in greater expenditure of mental effort, more errors, and longer completion task times.

The next chapter will describe the empirical study conducted to evaluate the quantitative approach developed in the study as accounting for intuitive use measured as low errors, time spent, and cognitive effort involved.

CHAPTER 5

A QUANTITATIVE APPROACH FOR MEASURING INTUITIVE INTERACTIONS

This chapter describes how the conceptual framework proposed in the previous chapter was used to quantify intuitive interactions in sets of products. The chapter is divided into three parts. The first part describes the empirical studies conducted to explore the concept of intuitive interactions based on image schemas; the second part illustrates how the proposed conceptual framework in Chapter 4 was applied to quantify intuitive interactions in products. The final part validates the quantitative approach results as a measure of intuitive interaction.

Overall, 126 observations were conducted, involving forty-two participants completing one task with three different alarm clocks. Although the methodology presented in this section is illustrated using interactions with only one of the products, the evaluation section includes the results of the full study, including all three products.

5.1 STUDY DESIGN (STUDY 1)

The first empirical study was conducted to evaluate the conceptual framework proposed in the previous chapter. The hypothesis tested is that a close match between the image schemas of the designer and those of the users should improve intuitive interaction. In concrete terms, the more image schemas were correctly identified in the task during interaction by the proposed methods, the higher the quantification (Q) and the higher the intuitive use, measured by low time spent, errors made, and cognitive effort expended.

This study aims to:

1. Illustrate how the conceptual framework can be concretely applied to a set of products;

2. Examine the inter-rater reliability of image schemas extracted in the study;
3. Test the validity of Q as a measure of intuitive use, defined as leading to low numbers of errors made, time spent, and cognitive effort expended.

5.1.1 Participants

A pre-screening process was initially proposed to be used to select participants in the study. A minimum of forty participants was proposed to be used in the study. The number of participants was chosen based on the similar previous studies (Macaranas, 2012, Blackler et al., 2003a, 2003b; Fischer et al., 2009; Hurtienne, 2011). The initial desire was to select the participants for the study from the pool of potential volunteers based on the participant prior experience of other products they have used in the past and gender. To this end, screening questionnaires (See Appendix B for the screening questionnaires) were distributed to eighty potential volunteers. Only forty-two completed and returned the screening questionnaires. Consequently, all the participants that returned the screening questionnaires were thereafter recruited for the study based on availability. The breakdown shows 13 females, age range from 22 to 43 years (mean=30.54, SD=6.05), and 29 males, age range from 22 to 45 years (mean=30.31, SD=5.07). None of the participants had prior experience with the product used in the study. Each volunteer received £6 for participating in the study. The user study was approved by the ethics committee of the Cardiff University School of Engineering. The breakdown of participants' grouping is shown in Table 5.1.

Table 5.1: Participants' Grouping for the Study

Age group	Male	Female
20–25	4	3
25–30	11	4
30–35	10	4

>35	4	2
Total	29	13

5.1.2 Apparatus

Multi-functional alarm clocks were used in the study. The first alarm clock had nine features, including mode, set, time, timer, sound, up and down buttons, a non-interactive element, and display. The second alarm clock had seven features, comprising alarm on switch, alarm, hour, minute, timer, snooze button, and display. The features of the first two clocks are common to most digital products. The third alarm clock, an analogue brand, had six features, including alarm on switch, volume switch, time knob, alarm knob, snooze, and display. These products were chosen because they provided many interaction opportunities based on a wide range of image schemas. Figure 5.1 shows alarm clock 1 used in the study.

Figure 5.1: Alarm Clock 1 Used in the Study

The equipment used for the study comprised: Four digital video cameras, which recorded participants' interactions from four angles.

Eye tracking glasses

SMI eye tracking glasses is a video-based glasses technology integrated with audio recording (SMI, 2012). There are three stages involved in setting up the eye tracking glasses in the study. These include, design, recording and analysis phase.

Design phase

This involves determining participant's properties, conditions and hardware setting. One point calibration at a field distance of 1.5 m, a frequency of 50 Hz and tracking efficiency of between 97.2 – 98.7% was chosen for the study.

Recording phase

The second phase involves activating the IView of the eye tracking glasses software after calibration and hardware setting has been done. The glasses were used to record the hand movements and the verbal comments made by the participants during the study.

Analysis phase

The eye tracking glasses were connected to a laptop computer via a USB port. The laptop was installed with IView software. The SMI Be-gaze analyses the recording of the IView into quantitative data. The eye movement data recorded includes the numbers of searches and blinks of the participants. Searches involve the number of saccadic eye movements while completing a task. More saccades indicate more searching (Goldberg and Kotval, 1999). The number of blinks can be used as an index for measuring cognitive load (Bruneau et al., 2002). A lower blink rate is an indication of higher workload.

The functions of the equipment used in the experiment were explained to the participants prior to the experiment.

5.1.3 Procedure

The participants in the user study were given a task to set the alarm clock to 8.30 a.m. The task consisted of a sequence of five subtasks. Prior to the start of the experiment, the clock was in a 'normal' mode (i.e. not set to alarm mode), with the time set for 3.00 a.m. The participants were timed and observed during the task; all interactions were video recorded. Figure 5.2 shows a participant interacting with alarm clock 1 used in the study. A structured questionnaire (See Appendix C) was completed by the participants immediately following completion of the task. The questionnaires consisted of a series of relevant research questions and a subjective rating scale designed to measure users' cognitive efforts and satisfaction. Finally, an exit interview (see Appendix D) was conducted. Figure 5.3 shows a participant completing the questionnaire at the end of the task. The study lasted approximately 45 minutes per participant.

Fig 5.2: **Participant Interacting with Alarm Clock 1 Used in the Study**

Fig 5.3: Participant Completing the Questionnaire Used in the Study

Having described the first empirical study, the next section illustrates how the conceptual framework was applied to quantify intuitive interaction in products.

5.2 EVALUATION OF THE QUANTITATIVE APPROACH

The method adopted for evaluating the quantitative approach for measuring intuitive interaction in the product is described below. It follows the four phases proposed in the conceptual framework for evaluating intuitive interaction in products.

A. Goal Identification

The participants were asked to set the alarm time to 8.30 a.m. The task was broken down into a task sequence corresponding to the subtasks. The knowledge required to complete each subtask (based on the product documentation) is a proxy for the designer's intent for the subtask. The subtasks are listed below, as identified from the manual for alarm clock 1.

(i) Activate the alarm mode

(ii) Activate the set option

(iii) Set the hour mark

(iv) Set the minute mark

(v) Activate the set time

The users' interactions were recorded using all four methods mentioned earlier: direct observation, think aloud protocol, questionnaires, and interviews. Thereafter, the interaction task flow (Figure 5.4) was developed for the task from the product documentation. This enabled the experimenter to identify every step made by the users during the interaction.

B. Image Schema Extraction

Following the procedure discussed in Chapter 4, image schemas were extracted from the designer's intent, as shown in Table 5.2. The table shows the image schemas extracted from the task steps and product description for product 1. *Path, container, content*, and *compulsion* image schemas were extracted from the task steps of Product 1. For example, the *container* image schema was extracted from the words 'enter into'. The *container* image schema consists of a boundary separating the interior from the exterior and a portal that allows movement into the interior (Dodge and Lakoff, 2005). The 'normal' mode represents the location out of the container; the action word 'press' initiates a movement through the portal into the container, which represents the alarm mode. Similarly, *centre-periphery, matching, container, path, near-far*, and *bright-dark* were extracted from the product description. For example, the central location of the clock's screen creates a spatial relationship with the other features, instantiating the *centre-periphery* image schema. The screen represents the centre, while the other features represent the periphery.

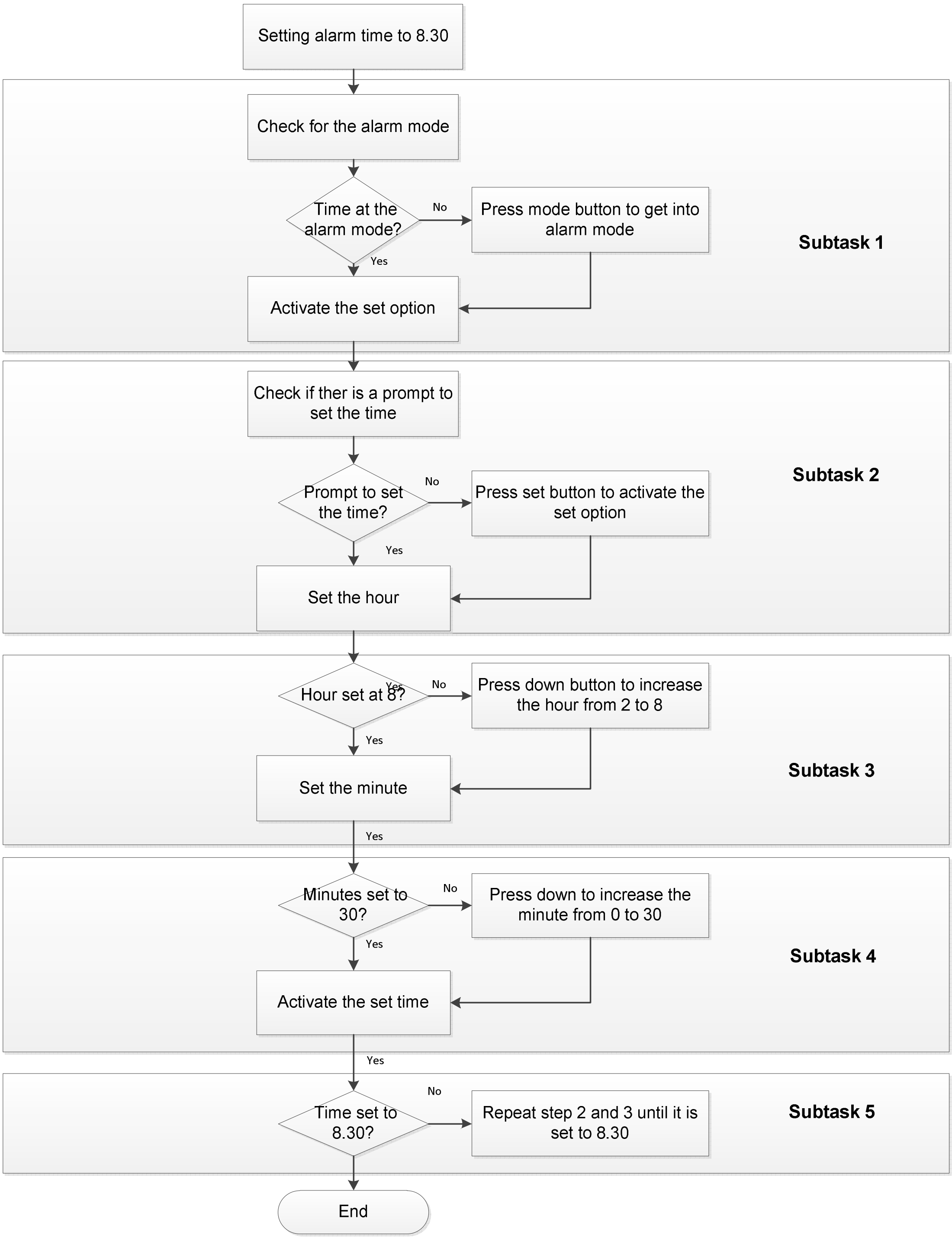


Figure 5.4: **Simplified Interaction Task Flow of the Alarm Time Task**

As shown in Table 5.3, the second stage extracted the identified image schemas from the user interactions to represent the user's model. The table shows the image schemas extracted from the direct observation, think aloud, questionnaires and interview. For example, the methodology used for extracting image schemas from the think aloud protocol is shown with a quote from the subject, such as, '*the mode button usually gives you an option of moving between the different modes, so that was why I pressed it*'. The *path*, *compulsion*, and *container* image schemas can be derived from the utterances of the participants. The image schema *path* involves a physical or metaphorical movement in space with a beginning, a goal, and a series of locations linking the beginning from the goal (Johnson, 1987). The movement between the modes was captured as a *path* image schema. The initial mode represents the start point or beginning; the final mode, the end-point or goal; the locations between the modes represent the path. *Compulsion* is a 'force' image schema that requires an external force physically or metaphorically, causing some passive entity to move (Johnson, 1987). The action word 'press' was captured as the external force of the users acting on the alarm clock, causing it to move from the initial mode to the final mode. All force image schemas are semantically related to *path* image schema, as force interaction always activates movement along a path (Pena, 1999). The *container* image schema was activated as a result of the movement from one mode into another, e.g., from normal mode to alarm mode. The 'moving between the different modes' quoted above was captured as a path into the *container*.

Table 5.2: Image Schemas Extracted from the Designer's Intent for Product 1

Methods	**Subtask**	**Quotes from the manual**	**Image schemas**	**Justification**
Task steps	Subtask 1	In the normal mode, press mode button to enter into alarm mode	Path	The *path* image schema is extracted. The structural component of the path consists of a starting point, and end point and a path linking the start point to the end point. The normal mode corresponds to the start point; the press action initiates a movement along a path to the end point which is the alarm mode.
			Container	The *container* image schema consists of a boundary separating the interior from the exterior and a portal that allows movement into the interior (Dodge and Lakoff, 2005). The *container* image schema is extracted from the word 'enter into'. The normal mode represents the location out of the container; the action word "press" initiate a movement through the portal into the container, which represents the alarm mode.
			Content	The *content* image schema, conceptualised from the container image schema, relates to everything in the container. The alarm mode represents the current location of the feature in the container.
			Compulsion	The *compulsion* image schema is a *force* image schema that involves an external force physically or metaphorically causing some passive entity to move (Johnson, 1987). The compulsion image schema is extracted from the action word 'press'. The external force in the form of the users physically pressing the button causes the passive entity (alarm clock) to move from the normal mode to the alarm mode. All force image schemas involve interaction resulting in movement along a path. To this extent, all force image schemas activate the path image schema (Pena, 1999).
Product	Subtask	The screen	Centre-	The *centre-periphery* consists of a centre, a periphery and a configuration.

description	1	display shows an icon of a clock at the normal mode that change to the icon of the bell in the alarm mode. The alarm mode displays a blinking colour in the background.	periphery Matching Attraction Path	The central location of the screen creates spatial relationship with other features. The screen represents the centre and the other buttons represents the periphery. The icon of the bell matches the alarm mode. The participants were quick to relate the sound made naturally by the bell with the alarm mode. The blinking of the background colour on the screen created an *attraction* image schema. The blinking drew the attention of participants to look at the feature on the screen. The change of the icon of the clock in the normal mode to the bell in the alarm mode represents the *path* image schema.
		The labels are written with text in white on a white background	Near- far Bright dark	The text written very close to the features activated the *near-far* image schema. The colour used for the text and background activated the *bright-dark* image schema. White (bright) on a white (bright).

Table 5.3: Image Schemas Extracted from User's interactions

Method	Quotes	Image schemas	Justification
Direct observation	Participants were observed to have pressed the mode button which activates the change from the normal mode to the alarm mode.	Compulsion Path Container	The press action initiates the movement from one mode to the other. The press action activates the *compulsion* image schema, while the change from one mode to the other activates the *path* image schema. The movement from the normal mode to the alarm mode represents the *container* image schema.
Think aloud	The mode button usually gives you an option of moving between the different modes, so that was why pressed it.	Path Container Compulsion	*Compulsion, path* and *container* image schemas are extracted. The 'movement between the different modes' represents the *path and container* image schemas. Caused motion involves contact between two forces, one of which set the other in motion (Pena, 1999). The action word 'press' represent the compulsion image schema. Compulsion image schema is an example of a caused motion. All caused motion is semantically related to *contact* image schema as physical or metaphoric contact is made for compulsion to be effective (ISCAT, 2012).
Questionnaire	The label on the mode button helped to complete the task.	Near-far	The *near-far* image schema is relevant for the task. The close button is grouped with a text label, which help participant to make sense of what the

		Enablement	feature stands for. The *enablement* image schema is relevant as the button possess the physical or metaphorical power to perform some act.
Interviews	I could not figure out quickly the features because of the poor colour used for the label	Bright dark Blockage	The image schema indicates differing participants experience as a result of the poor contrast used for the label and the background. The *bright-dark* image schema is activated. Using white (bright) text on a white (bright) background created the contrast problem. The poor colour practically redirects and slows down the participants view activating the *blockage* image schema.

The image schema identified and extracted from the designer's and the users' perspectives was collated by the experimenter for the three products used in the study. An independent evaluation study (Study 2) was conducted on the identified image schemas in Study 1.

B1. Study 2

The independent study (Study 2) was conducted in order to examine the reliability of the identified image schemas in Study 1. Hurtienne (2011), proposed an inter-rater reliability test, as a prerequisite for selecting image schemas used in the design phase. His recommendation was based on two empirical studies conducted using experts that are familiar with image schema analysis to reclassify image schemas usage scenario generated by eleven participants in an empirical study (Hurtienne, 2011).

To this end, two independent evaluators with experience in image schema analysis were recruited for the study. Both evaluators are experts in product and interaction design respectively. They were given the task of extracting image schemas from the same task in study 1. The evaluators were presented with the two sets of data from Study 1: The data include a transcript from the participants think aloud data and task steps and product description from the manual. In addition, the list of the image schemas and their description (See Appendix E:1), as well as the three products used in the study are also displayed. The list of the image schemas and their description provided the independent evaluator a common base to draw from. It has been found that a large amount of disagreement can be minimised if evaluators applies a common rule for image schemas extraction (Hurtienne, 2011). They were asked to extract image schemas from the document containing the think aloud protocol of the participants and the task steps and product description from the manual. The raters worked together while extracting the image schemas. Fifteen participant's think aloud transcriptions were randomly selected from the study for extraction. The number was assume to be adequate as the participants transcript are repetion of most of the image schemas identified in the task. At the end of the task, the image schemas extracted from the think aloud and the manual for the three products were collated for each evaluator.

Following that, the strength of agreement of the image schemas identified by the independent evaluators as relevant for the task was conducted using the Cohen kappa coefficient, *k*. This was calculated as:

$$k= P(\alpha) – P(\varepsilon)/1– P(\varepsilon) \qquad \text{Eqn 5.1}$$

where $P(\alpha)$=observed agreement between evaluators

$P(\varepsilon)$=probability of chance agreement

Chance agreement was taken to be 50 percent, since two options were possible for the independent evaluators: either an agreement or disagreement with the image schemas identified by the experimenter for the completion of the task in the first study. An agreement indicated the relevant image schemas were correctly extracted for the task, while a disagreement showed that the image schemas were not relevant to the task, hence incorrectly extracted. Tables 5.4, 5.5 and 5.6- shows the image schema extracted by the independent evaluators and their *k* values for the three products used in the study. As mentioned in Chapter 4, a *k* value above 0.6 was proposed as a benchmark for selecting the image schemas used in the analysis phase. Eight image schemas had a strength value *k* above 0.6 in Product 1. These image schemas comprised *container, path, bright-dark, attraction, matching, centre-periphery, compulsion*, and *up-down*.

Table 5.4: Image Schemas Extracted by Independent Evaluators for product 1

Image extracted by the experimenter	Evaluator 1						Evaluator 2						K value User	K value Designer
	User's Interaction			Designer's intent			User's interaction			Designer's intent				
	Accurate	Inaccurate	Observed Agreement	Accurate	Inaccurate	Observed Agreement	Accurate	Inaccurate	Observed Agreement	Accurate	Inaccurate	Observed Agreement		
Container	7	1	87.5	4	0	100	6	2	75.00	4	1	80	0.63	0.81
Content	2	1	66.67	1	3	25	2	1	66.67	1	3	25	0.34	0.51
Attraction	3	0	100	3	0	100	3	0	100	3	0	100	1.00	1.00
Compulsion	5	0	100	5	0	100	5	0	100	5	0	100	1.00	1.00
Centre-periphery	4	1	80	5	0	100	5	0	100	5	0	100	0.81	1.00
Path	3	1	75	4	0	100	3	1	75	1	0	100	0.51	1.00
Up-down	5	1	83.33	2	0	100	5	1	83.33	4	0	100	0.68	1.00
Matching	2	0	100	2	0	100	2	0	100	2	0	100	1.00	1.00
Bright dark	3	0	100	1	0	100	3	0	100	1	0	100	1.00	1.00
Part-whole	2	1	66.67	0	1	0	2	1	66.67	0	`1	0	0.34	0.00
Near-far	0	0	0	0	0	0	0	0	0	0	0	0	-	-

Table 5.5: Image Schemas Extracted by Independent Evaluators for product 2

Image extracted by the experimenter	**Evaluator 1**						**Evaluator 2**						**K value User**	**K value Designer**
	User's Interaction			**Designer's intent**			**User's Interaction**			**Designer's intent**				
	Accurate	Inaccurate	Observed Agreement	Accurate	Inaccurate	Observed Agreement	Accurate	Inaccurate	Observed Agreement	Accurate	Inaccurate	Observed Agreement		
Container	1	0	100	1	0	100	1	0	100	1	0	100	1.00	1.00
Content	1	0	100	1	0	100	1	0	100	1	0	100	1.00	1.00
Attraction	3	0	100	2	0	100	3	0	100	2	1	66.67	1.00	0.68
Compulsion	5	0	100	3	0	100	5	0	100	3	0	100	1.00	1.00
Centre-periphery	1	0	100	2	0	100	1	0	100	2	0	100	1.00	1.00
Path	3	0	100	3	0	100	3	0	100	2	1	66.67	1.00	0.68
Up-down	2	0	100	1	0	100	2	0	100	1	0	100	1.00	1.00
Matching	2	0	100	1	0	100	2	0	100	1	0	100	1.00	1.00
Bright dark	1	0	100	1	0	100	1	0	100	1	0	100	1.00	1.00
Restraint remover	1	2	33.33	2	0	100	2	1	66.67	2	0	100	0.02	1.00
Left- right	0	2	0	0	1	0	2	0	100	1	0	100	0.02	0.02

Table 5.6: Image Schemas Extracted by Independent Evaluators for product 3

Image extracted by the experimenter	Evaluator 1						Evaluator 2						K value User	K value Designer
	User's Interaction			Designer's intent			User's Interaction			Designer's intent				
	Accurate	Inaccurate	Observed Agreement	Accurate	Inaccurate	Observed Agreement	Accurate	Inaccurate	Observed Agreement	Accurate	Inaccurate	Observed Agreement		
Container	2	0	100	1	0	100	2	0	100	1	0	100	1.00	1.00
Content	2	0	100	1	0	100	2	0	100	1	0	100	1.00	1.00
Attraction	1	0	100	1	0	100	1	0	100	1	0	100	1.00	1.00
Compulsion	2	0	100	2	0	100	2	0	100	2	0	100	1.00	1.00
Centre-periphery	2	0	100	1	0	100	2	0	100	1	0	100	1.00	1.00
Path	1	0	100	1	0	100	1	0	100	1	0	100	1.00	1.00
Up-down	1	0	100	1	0	100	1	0	100	1	0	100	1.00	1.00
Matching	3	0	100	1	0	100	3	0	100	1	0	100	1.00	1.00
Bright dark	1	0	100	1	0	100	1	0	66.7	1	0	100	0.68	1.00
Front-back	4	0	100	2	0	100	4	0	100	2	0	100	1.00	1.00
Left- right	0	2	0	1	0	100	2	0	100	1	0	100	0.02	1.00
Rotation	5	0	100	2	0	100	5	0	100	2	0	100	1.00	1.00

Cycle	2	0	100	1	0	100	2	0	100	1	0	100	1.00	1.00
Link	2	0	100	1	0	100	0	2	0	1	0	100	0.02	1.00
Big small	0	1	0	1	0	100	1	0	100	1	0	100	0.02	1.00

C. Image schema analysis

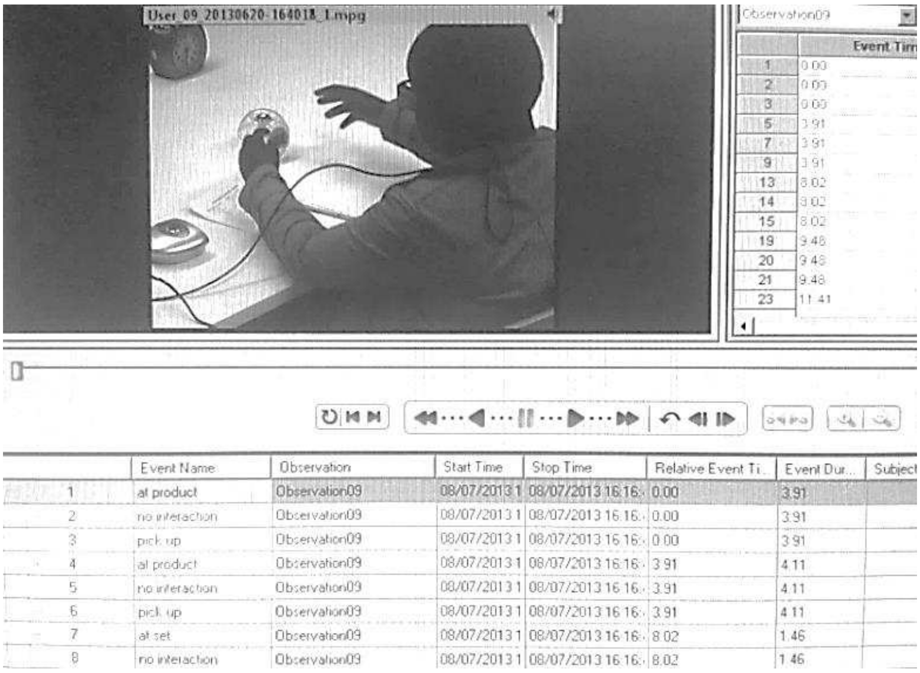
Following the same procedure based on the conceptual framework, this phase compared the image schemas extracted from the designer's and users' perspectives using the coding developed in Table 4.1. The coding categories adopted for the study were applied in the analysis. The image schemas used, and their categories, were identified from each subtask based on the four methods adopted in the study. Table 5.7 contains examples of quotes from each category in the study. For example, for the completion of subtask 3, the *compulsion* image schema was identified to be correctly used in accordance with the designer's intent, and as such was coded as Category 1. The participant was certain about the image schema used in the interaction. In contrast, the *up-down* image schema was identified to be incorrectly used in accordance with the designer's intent, based on the transcript of the think aloud used for completing the task. As mentioned earlier in the description of the conceptual framework, in cases where there were conflicts in terms of the categories of the four methods, the decision rules developed were applied to resolve such discrepancies.

Table 5.7: Examples of Quotes Extracted from each Category for Product 1

Quotes	**Subtask**	**Categories**		
		Correct	**Incorrect**	**Trial and error**
'I know mode button gives the option to choose from that was I pressed it. I pressed the mode button and saw the icon of the bell'.	1	Path Compulsion Attraction Matching	-	-
'In my mind, I know when I press the button at the top, the hour will increase, but it is not working like that here'.	3	Compulsion	Up- down	-
'I am confused. I don't know what to do. I am just trying out this thing'.	5	-	-	None

Thereafter, the performance data of the participants were analysed using the Noldus Observer XT10 software shown in Figure 5.5. The performance data, which included time on task and the number of errors made while completing the task, were processed from the video recording of the participants. As stated earlier, the cognitive effort expended in completing the task was processed from the rating scale in the questionnaire.

Figure 5.5: Data Analysis of a Participant within Observer XT10 Software



D. Image schema assessment

The goal of the fourth phase was the quantitative assessment of intuitive interactions based on the image schemas that fell into Category 1. This was calculated as the ratio of the sum of the percentages of times each particular identified image schema was correctly used by the participants over the number of image schemas represented in the design for the completion of the task. For the completion of subtask 3 using Product 1, eight image schemas were employed for the completion of the subtask. The quantitative assessment revealed that three image schemas were correctly used in accordance with the designer's intent (Category 1). The image schemas included *container, compulsion*, and *centre-*

periphery. Using equation (4.1), with p=1, intuitive interaction was quantified as 37.50 percent for the subtask by the participant.

The image schemas used for the completion of all the subtasks were then computed for the three products used in the study, as shown in Table 5.8. These values represent the percentages of the image schemas used by all participants in accordance with the designer's intent (Category 1), known in the study as quantification 'Q'. Appendix F shows the Q value computed for each image schema identified to be used for completing the task by all the participants in Study 1.

Table 5. 8: Image Schemas Used for the Completion of the Task by all Participants

	Product 1				**Product 2**				**Product 3**			
	Category 1	Category 2	Category 3	Q value	Category 1	Category 2	Category 3	Q value	Category 1	Category 2	Category 3	Q value
1	2	3	3	0.250	4	1	7	0.333	2	3	5	0.200
2	4	2	2	0.500	5	3	4	0.416	4	3	3	0.400
3	2	2	4	0.250	4	1	7	0.333	3	1	6	0.300
4	3	2	3	0.375	4	1	7	0.333	2	1	7	0.200
5	5	3	0	0.625	7	0	5	0.583	4	2	4	0.400
6	7	1	0	0.875	6	1	5	0.500	5	2	3	0.500
7	6	1	1	0.750	7	2	3	0.583	4	2	4	0.400
8	2	2	4	0.500	6	2	4	0.500	2	3	5	0.200
9	5	3	0	0.625	6	1	5	0.500	4	2	4	0.400
10	4	2	2	0.500	5	2	5	0.416	2	1	7	0.200
11	6	1	1	0.625	8	0	4	0.666	5	2	3	0.500
12	2	4	2	0.250	6	1	5	0.500	4	1	5	0.400
13	2	1	5	0.250	5	1	6	0.416	2	1	7	0.200
14	2	1	5	0.250	6	1	5	0.500	3	0	7	0.300

15	5	3	0	0.625	6	2	4	0.500	2	2	6	0.200
16	3	1	4	0.375	5	1	4	0.416	2	1	7	0.200
17	3	1	4	0.375	4	2	6	0.333	3	2	5	0.300
18	2	2	4	0.250	6	2	4	0.500	3	1	6	0.300
19	3	2	3	0.375	5	2	5	0.416	2	1	7	0.200
20	4	1	3	0.500	5	2	5	0.416	2	1	7	0.200
21	6	0	2	0.750	4	2	6	0.333	3	2	5	0.300
22	3	2	3	0.375	5	3	4	0.416	2	3	5	0.200
23	3	1	4	0.375	4	2	6	0.333	3	2	5	0.300
24	2	2	4	0.250	4	4	4	0.333	2	1	7	0.200
25	4	1	3	0.500	6	1	5	0.500	5	2	3	0.500
26	4	3	1	0.500	5	2	5	0.416	4	2	4	0.400
27	3	2	3	0.375	6	1	5	0.500	2	1	7	0.200
28	7	1	0	0.875	4	4	4	0.333	5	2	3	0.500
29	3	1	4	0.375	4	2	6	0.333	2	2	6	0.200
30	2	1	5	0.250	4	3	5	0.333	2	2	6	0.200
31	2	1	5	0.250	4	2	6	0.333	2	1	7	0.200
32	3	1	4	0.375	4	1	7	0.333	2	3	5	0.200
33	2	2	4	0.250	4	2	6	0.333	3	2	5	0.300
34	3	3	2	0.375	4	2	6	0.333	3	2	5	0.300
35	2	1	5	0.250	5	1	6	0.416	3	1	6	0.300
36	4	1	3	0.500	4	1	7	0.333	5	3	2	0.500
37	4	1	3	0.500	4	1	7	0.333	2	1	7	0.200
38	3	2	3	0.375	3	1	8	0.250	4	1	5	0.400
39	3	1	4	0.375	3	0	9	0.250	2	1	7	0.200
40	4	1	3	0.500	5	3	4	0.416	5	2	3	0.500

41	4	1	3	0.500	4	2	6	0.333	2	2	6	0.200
42	4	1	3	0.500	7	2	3	0.583	6	2	2	0.600

5.3 EVALUATION RESULTS

As mentioned earlier, the quantitative measurement of intuitive interaction is based on equation (4.1). The hypothesis tested is that a close match between the image schemas of the designers and those of the users should improve intuitive interaction and it will lead to a larger value of ‘Q’. It is expected that as the ‘Q’ value (approach use for measuring intuitive use in the study) increases, the time to complete task decreases, the errors made are fewer and less cognitive effort is required to complete the task.

To test this hypothesis, participants that successfully completed the task were grouped using the ‘Q’ value. The participant ‘Q’ values were ranked in ascending (lowest to the highest) order and then split into two groups. The median was used as a base for splitting the participants into low and high group. It is expected that as the ‘Q’ value (approach use for measuring intuitive use in the study) increases, the time to complete tasks decreases, the errors made are fewer and less cognitive effort is required to complete the task. In concrete terms, it means the higher the ‘Q’ value of the participant, the more intuitive is the interaction as measured by quicker time on task (efficiency), fewer number of errors (effectiveness) and less cognitive effort expended in completing the task.

Statistical analysis was then conducted in order to examine how quantification (Q) accounted for intuitive use as measured by the time on tasks, errors, and cognitive effort, using SPSS 20.0. Outliers in the three dependent variables (time, errors, and cognitive effort) were determined by examination of the boxplots. Effect size was computed using the Becker (2000) effect size calculator. An effect size d of 0.20 would be considered as small, 0.50 as medium, and 0.80 as high (Cohen, 1988). A Shapiro-Wilks test was used to determine if the dependent variables (time, error, and cognitive effort) were normally distributed. If the Shapiro-Wilks test results were greater than 0.05, the variable would be considered to be normally distributed, and below 0.05, the variable would deviate significantly from normal distribution (Laerd, 2013). The homogeneity of variance test was conducted using Levene's test of equality of variance. A Levene's test result of less than 0.05 indicated that homogeneity of variance was violated; hence a Welch correction test was used for dependent variables. A Levene's test of more than 0.05 indicated that homogeneity of variance was observed in the variable; hence a normal parametric test was conducted (Laerd, 2013). An independent t-test was used to determine if there were significant differences in the three variables (time to complete task, errors, and cognitive effort) in the two groups (levels of quantification).

5.3.1 Time on Task

The mean and standard deviation time on task were computed for the three products used in the study, as shown in Table 5.9.

Table 5.9: Mean and Standard Deviation Time on Tasks in the Two Groups

	Variable	**No**	**Quantification, Q Low**		**Quantification, Q High**	
			Mean	SD	Mean	SD
Product 1	Time (s)	15	61.01	43.00	22.30	10.42
Product 2	Time (s)	10	94.24	61.78	39.30	18.75
Product 3	Time (s)	11	45.22	26.53	17.14	13.64

An independent t-test was run to determine if there were significant differences in times to complete the task in the two groups (low and high quantification) in the three products. For Product 1, there were no outliers in the data, as assessed by inspection of a boxplot, as shown in Figure 5.6. A Shapiro-Wilks test (p=0.42) showed that the times to complete the tasks were approximately normally distributed for the two groups, with effect size (d=1.23). Homogeneity of variance was violated, as assessed by the Levene test of equality of variance (p= 0.001), so separate variances and the Welch correction were used. For the variable time on task and levels of quantification, the results revealed that a statistical difference existed between the participants' time to complete the task in the two groups (high and low quantification) for Product 1: $t(28)=3.39$, $p<0.05$. Similarly, for Products 2 and 3, there were statistical differences in time to complete the task in the two groups: Product 2: $t(18)=2.70$, $p<0.05$; Product 3: $t(20)=3.12$, $p<0.05$. These results indicate that participants with high quantification ('Q' value) were significantly quicker while completing all subtasks with the three products used in the study.

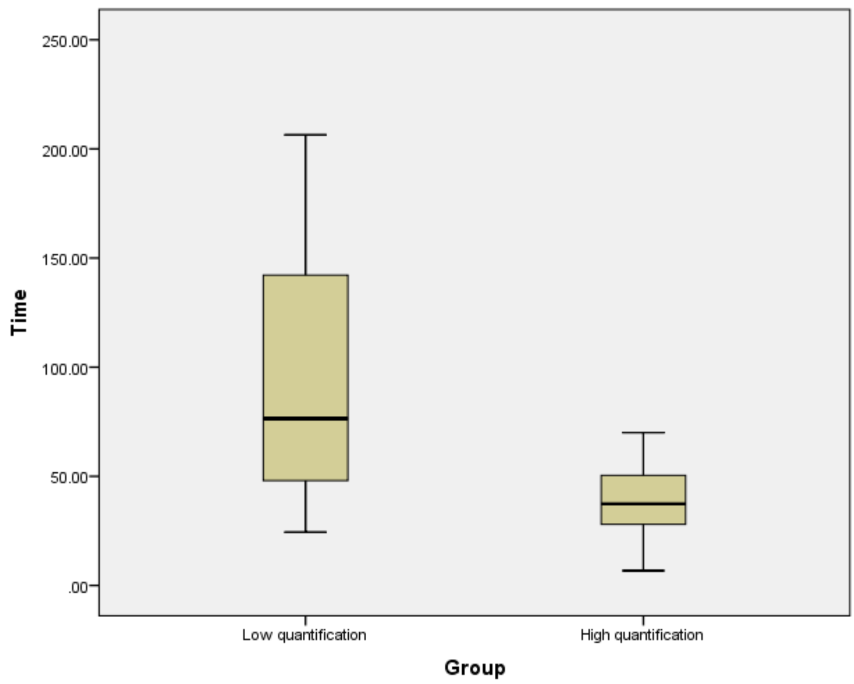


Figure 5.6: Boxplot to Determine Outliers in the Two Groups' data

Thereafter, the relationship that exists between time on task and the quantification (Q) values of the participants were examined using the Pearson correlation test. Figures 5.7, 5.8, and 5.9 show the relationship between the two variables for the three products. The results reveal a strong negative correlation between quantification Q and time on task for the three products: Product 1: $r(28)=-0.70$, $p<0.05$; Product 2: $r(18)= -0.77$, $p<0.05$; Product 3: $r(20)=-0.62$, $p<0.05$. These results suggest that as the Q values increase, the efficicncy of the participants' increases in terms of quicker task completion time.

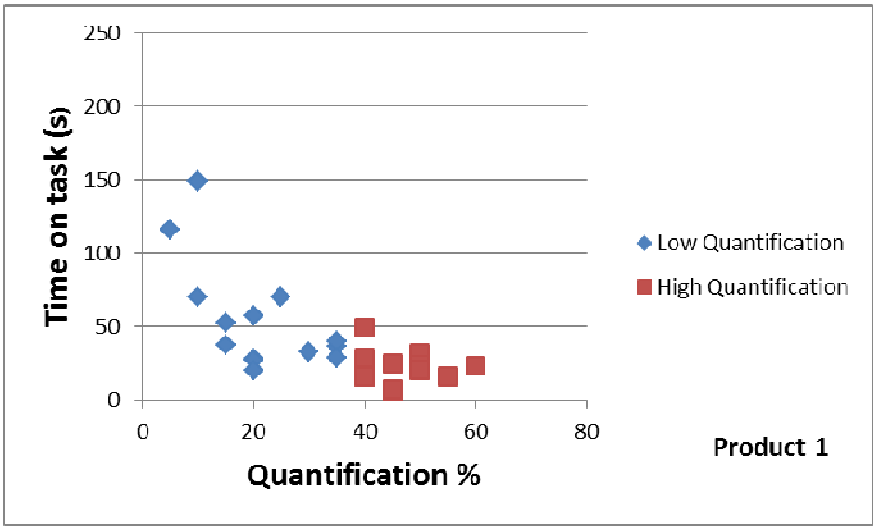


Figure 5.7: Quantification Plotted Against Time on Task for Product 1

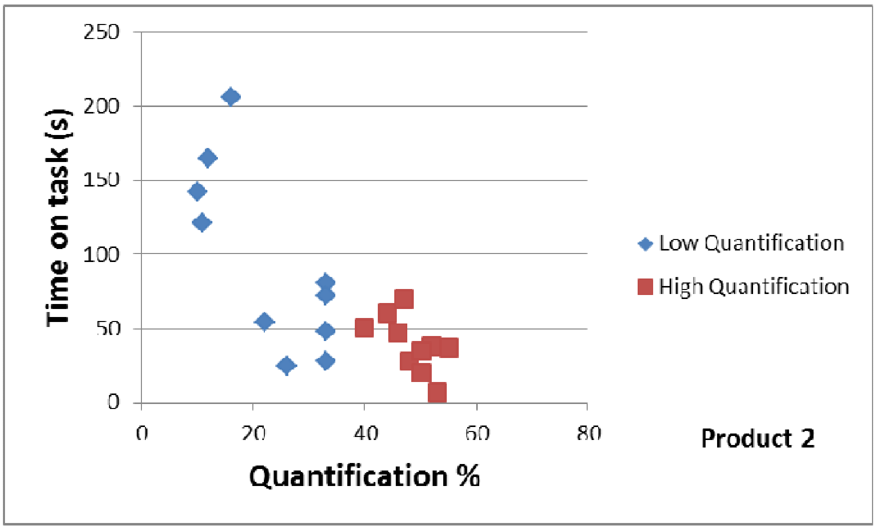


Figure 5.8: **Quantification Plotted Against Time on Task for Product 2**

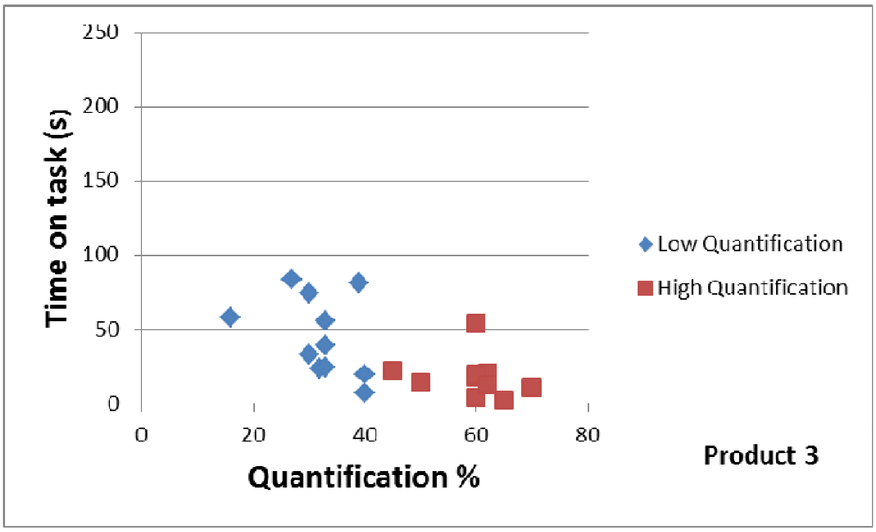


Figure 5.9: Quantification Plotted Against Time on Task for Product 3

5.3.2 Errors

Similarly, the mean and standard deviation of the number of errors made while completing the task were computed for the three products as shown in Table 5.10.

Table 5.10: Mean and Standard Deviation Number of Errors in the Two Groups

	Variable	No	Quantification, Q Low		Quantification, Q High	
			Mean	SD	Mean	SD
Product 1	Errors	15	6.13	5.12	3.13	2.70
Product 2	Errors	10	13.20	8.20	7.90	3.60
Product 3	Errors	11	1.45	1.30	0.45	0.68

An independent t-test was run to determine if there were differences in the number of errors between the levels of quantification (low and high) in the three products. For Product 1, there were no outliers in the data, as assessed by inspection of the boxplot shown in Figure 5.10. A Shapiro-Wilks test (p=0.19) showed that the numbers of errors made while completing the task were approximately normally distributed for the two groups, with effect size (d=0.73). Homogeneity of variance was breached, as assessed by the Levene test of equality of variance ($p=0.025$), so separate variances and the Welch correction were used. For the variable number of errors and levels of quantification, the results revealed that a statistical difference existed between participants' number of errors made while completing the task in the two groups (high and low quantification) for Product 1: $t(28)=2.00$, $p<0.05$ and Product 3: $t(20)=2.26$, $p<0.05$. There was no statistically significant difference (n.s.) in the number of errors in the two groups for Product 2: $t(18)=1.87$, $p=0.078$ (n.s.). These results indicated that participants in the high Q value group were more effective in terms of fewer errors made while completing the task compared to the low Q value group.

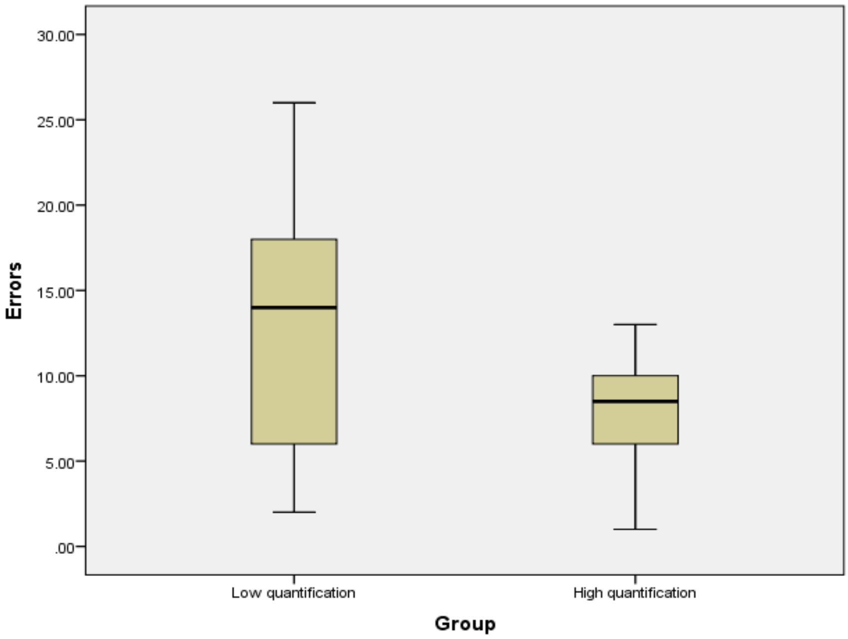


Figure 5.10: Boxplot to Determine Outliers in the Two Groups' Data

The relationship that exists between number of errors and the Q values of the participants was then examined using the Pearson correlation test. Figures 5.11, 5.12, and 5.13 show the relationship between the two variables for the three products. The results revealed a negative correlation between quantification Q and the number of errors in the three products: Product 1: $r(28)=-0.57$, $p<0.05$; Product 2: $r(18)=-0.64$, $p<0.05$; Product 3: $r(20)=-0.44$, $p<0.05$.

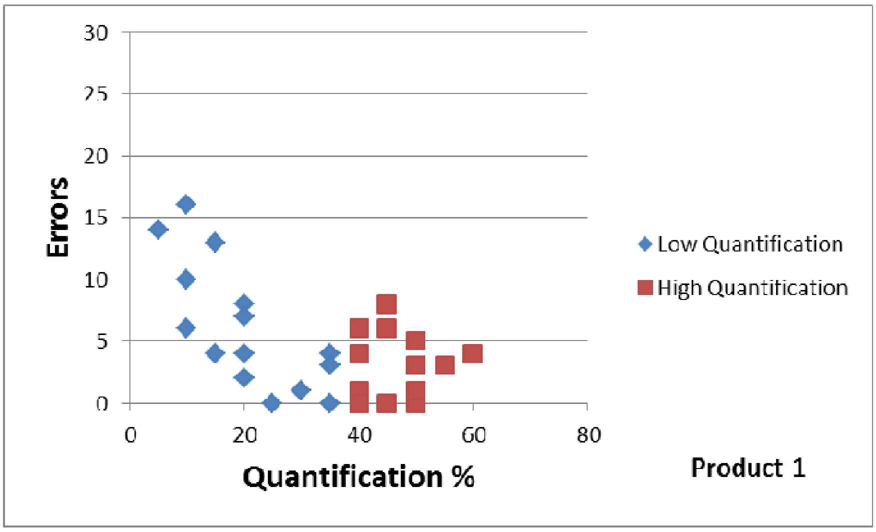


Figure 5.11: Quantification Plotted Against Errors for Product 1

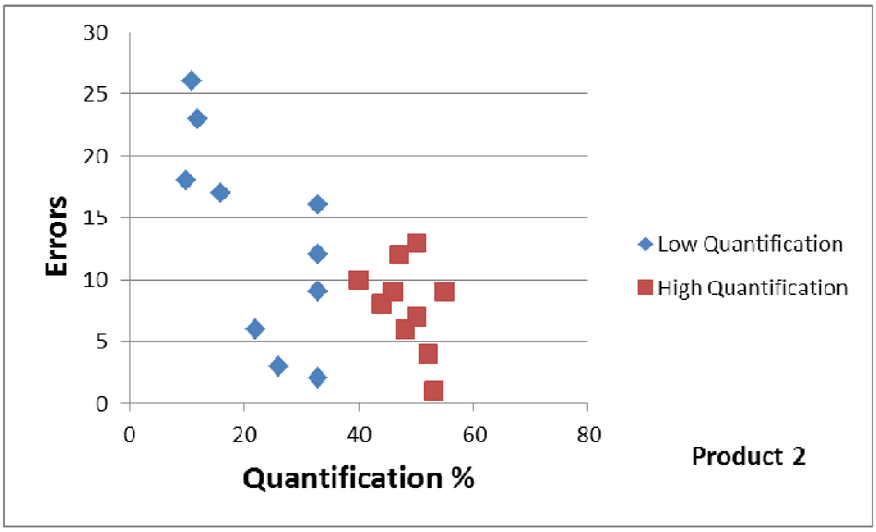


Figure 5.12: Quantification Plotted Against Errors for Product 2

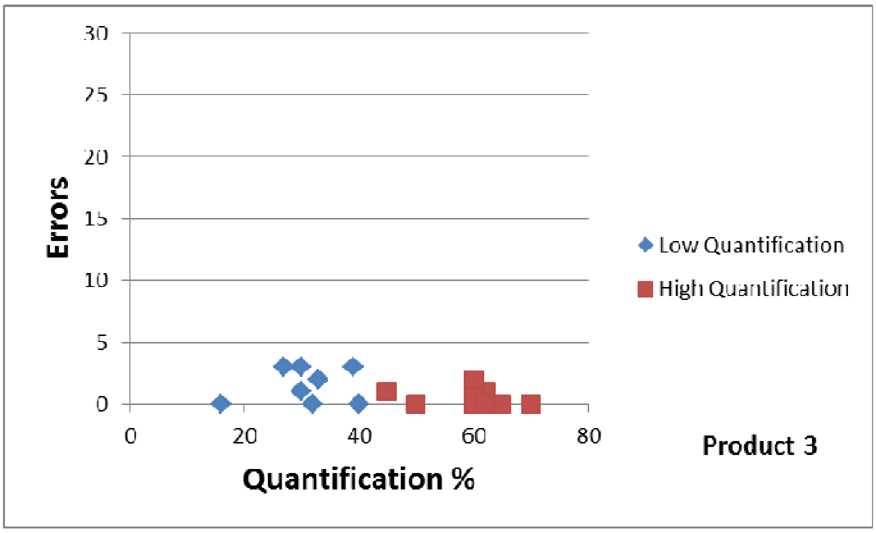


Figure 5.13: Quantification Plotted Against Errors for Product 3

5.3.3 Cognitive Effort

The mean and standard deviation for cognitive effort expended in completing the task were computed for product 3 as shown in Table 5.11.

Table 5.11: Mean and Standard Deviation Cognitive Effort in the Two Groups

Variable	No	Quantification, Q Low		Quantification, Q High	
		Mean	SD	Mean	SD
Cognitive effort	15	2.13	0.74	3.20	0.94
Cognitive effort	10	1.70	0.67	3.10	0.87
Cognitive effort	11	3.00	1.18	4.63	0.80

An independent t-test was conducted to determine if there were differences in cognitive effort expended between the levels of quantification (low and high) in the two products. For Product 1, there were no outliers in the data, as assessed by inspection of a boxplot. A Shapiro-Wilks test (p=0.50) showed that the cognitive effort expended while completing the task was approximately normally distributed for the two groups, with effect size (d=1.26). Homogeneity of variance was observed, as assessed by the Levene test of equality of variance (p=0.678), so the normal parametric test was used. For the variable cognitive effort and levels of quantification, the results revealed that a statistically significant difference existed between the participants' cognitive effort made while completing the task in the two groups (high and low quantification) for the three products: Product 1: $t(28)=3.73$, $p<0.05$; Product 2: $t(18)=4.00$, $p<0.05$; and Product 3: $t(20)=3.78$, $p<0.05$. These results indicate that participants with high Q values expended less cognitive effort while completing all subtasks with the three products used in the study.

The relationship that exists between cognitive effort and the Q values of the participants was then examined using the Pearson correlation test. Figures 5.14, 5.15, and 5.16 show the relationship between the two variables for the three products. The results revealed a strong negative correlation between Q and cognitive effort expended on the task for the three products: Product 1: $r(28)=-0.60$, $p<0.05$; Product 2: $r(18)=-0.65$, $p<0.05$; and Product 3: $r(20)=-0.65$, $p<0.05$. These results suggest that as the quantification Q value increased, the cognitive effort expended on the tasks decreased.

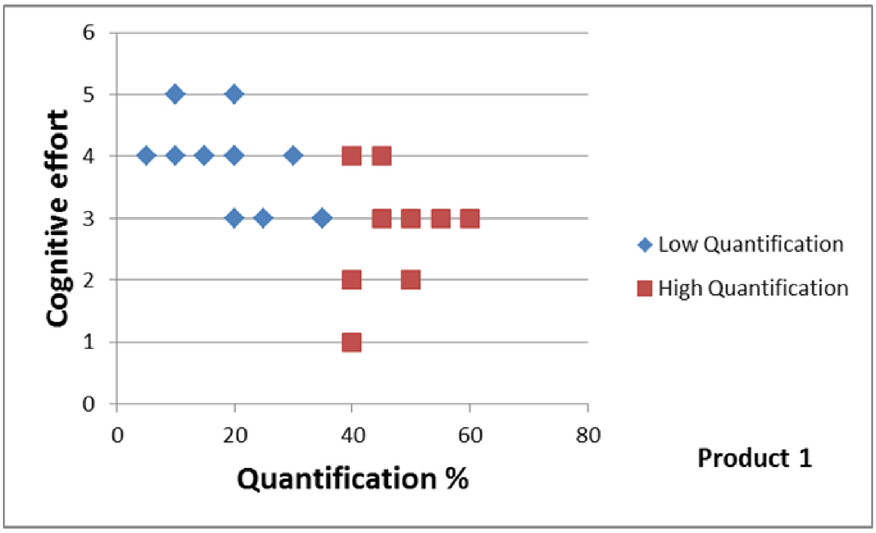


Figure 5.14: Quantification Plotted Against Cognitive Effort for Product 1

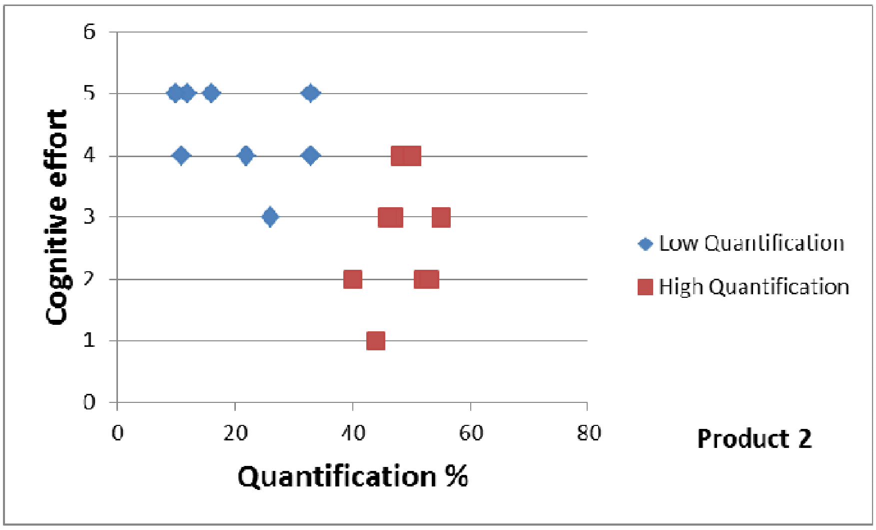


Figure 5.15: **Quantification Plotted Against Cognitive Effort for Product 2**

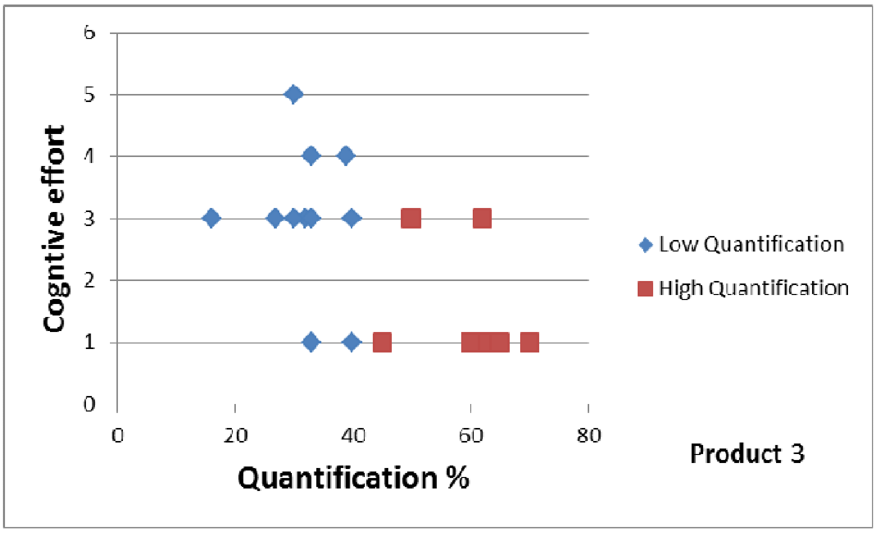


Figure 5.16: **Quantification Plotted Against Cognitive Effort for Product 3**

5.4 DISCUSSION

The study has shown that the Q values (the approach used to measure intuitive interaction in the study) and the variables used to operationalise intuitive use in the study (task time, errors, and cognitive effort) indicate strong negative correlations across the three products used in the study. Specifically, it was observed that there were statistical differences between time on task, cognitive effort, and errors in the two groups (high and low quantification) for the three products used in the study. The only exception was the variable 'error' for Product 2, which had a p value of 0.07, against the standard significant value of

0.05. Overall, the results in the first study validated the hypothesis in terms of the relationship that exists between quantification Q and the variables time, errors, and cognitive effort in the three products. These relationships suggest that participants with high Q values tended to rate the cognitive effort expended as low, made fewer errors, and were quicker to complete the task. Table 5.12 shows a summary of the validation results for the three products used in the study.

Table 5.12: Summary of the t-test Validation Results for the Products Used in the Study

	Independent t-test		
	Time on task	**Errors**	**Cognitive ratings**
Product 1	t(28)= 3.39, p<0.05	t(28)= 2.00, p<0.05	t(28)= 3.73, p<0.05
Product 2	t(18)= 2.70, p<0.05	t(18)= 1.87, p<0.07 (n.s)	t(18)= 4.00, p<0.05
Product 3	t(20)= 3.12, p<0.05	t(20)= 2.26, p<0.05	t(20)= 3.78, p<0.05

In addition, the image schemas used for the completion of the task were analysed separately at a deeper level. Across the three products used for the completion of the task, it was observed that image schemas with low Q values were responsible for the task difficulties experienced by the majority of the participants. For Product 1, these image schemas included *matching* (40.5*), bright-dark* (14.3), *attraction* (21.4), *up-down* (16.6), and *path* (9.5). The breakdown of these individual image schemas shows that the *matching, bright-dark*, and *attraction* image schemas represented the appearance of the interface. The *up-down* image schema represented the arrangement, which captures the spatial location of the feature. The *path* image schema represented the step-by-step use of the feature, which captures the function of the feature. Similarly, for Product 2, *restraint remover* (4.2), *path*

(12.5), and *matching* (10.6) were observed to have low quantification, while Product 3 included *path* (32.6), *bright-dark* (12.0), and *attraction* (12.2).

Further analysis of these image schemas responsible for the task difficulties across the three products used in the study showed that the *path* and *restraint remover* image schemas impacted negatively on the participants' performance in terms of the function. These two image schemas control the step-by-step procedure for completing the task. The *up-down* image schema affected the participants in terms of the location, while *matching, bright-dark*, and *attraction* image schemas affected them in terms of appearance. The Q value of the image schemas used for the task could have been increased substantially if the right convention, in terms of the arrangement of the features, were maintained; presenting the features with bright attractive colours; and using an appropriate icon that was meaningful to the user. These findings are in agreement with previous studies, that intuitive interaction is facilitated by designing an interface using familiar shapes, sizes, and colours for performing well-known functions and when placed in a familiar location (Blackler, 2006).

The approach developed in the current study is user-centred based. As shown in Figure 5.17, the proposed approach has the potential to evaluate intuitive usage at the different phases of the user-centred process. For example, in the design for intuitive use phase, the appearance of the feature, comprising size, colour and icon, captured as the product semantics can be represented with *big-small, bright-dark, attraction* and *matching* image schemas. These image schemas can be evaluated quantitatively based on the proposed approach.

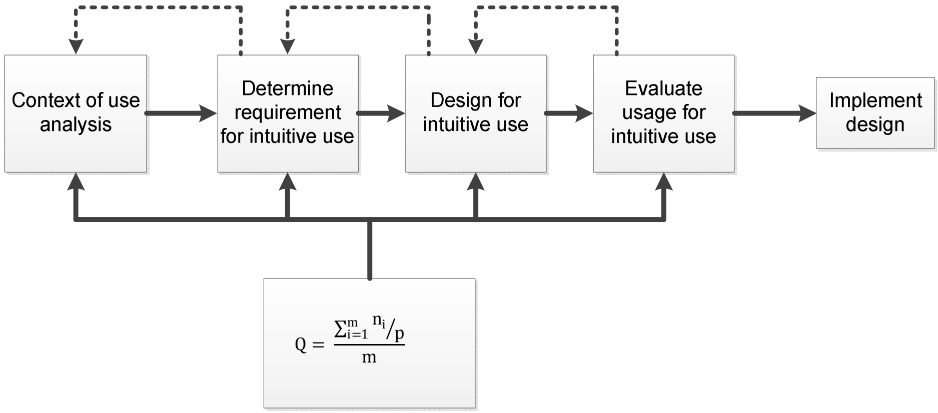


Figure 5.17: A user-centred Evaluation of Intuitive Use

While conducting the first study, a few issues were observed in the implementation of the methodology. For example, it was observed that image schemas identified in the think aloud of the participants could be nested; that is, having more than one image schema interplay in the context of the users' speech. Furthermore, during the independent evaluation study, it was observed that the independent evaluators adopted different rules for extracting the image schemas identified to be relevant in the context of the transcribed speech, and provided justification for their choices. This can be very problematic in terms of implementation. The context and information available at the disposal of the evaluators was observed to have played a great role in determining the image schemas identified. Although increasing the numbers of evaluators can boost the chances of identifying more image schemas than was seen in the study, this will have an attendant effect on the cost of implementing the methodology. One way to address this problem would be to develop a systematic approach based on a formalised, uniform set of rules for extracting image schemas.

Secondly, it was also observed that two of the four methods adopted in the study contributed less to identifying the image schemas used by the participants. Across the three products used in the study, direct observation contributed significantly, at a mean percentage of 84.31 percent, followed by the think aloud protocol, at 58.4 percent. The questionnaire (47.05) and interview (46.35 percent) contributed less for identifying the type of use. Considering the enormous effort involved in implementing the methodology for extracting image schemas, the position of this study is that direct observation and the think aloud protocol would be sufficient for identifying the image schema in future studies.

In addition, the eye tracking glasses were initially proposed to be used as one of the means for measuring the cognitive effort of the participants using their blink rate. The blink rate is a physiological eye measurement metric for indicating the cognitive workload of a user. The results were not encouraging; hence the self-reported mental rating was used for measuring the cognitive workload in this study.

5.5 SUMMARY

The study revealed that image schemas that appeared in the three categories (correctly used, incorrectly used, and trial and error) were applied during the interaction by all the participants. It was observed that these image schemas identified interplay in the context of the task swinging from one mode of processing to the other. The image schemas that appeared in Categories 2 and 3 activated more of the analytical processing mode in the majority of the participants. These were identified from participant think aloud, direct observation, questionnaires, and interviews.

This study shows that by using a method for the quantification of image schema matching, interaction difficulties can be coded in terms of image schemas; this has the potential to lead to improved interaction design, and may provide a new structured approach to usability testing. The study uses the degree of match of image schemas employed by the participants in accordance with the designer’s intent as the basis for the evaluation. Image schemas that fell into Categories 2 and 3 (namely those with low Q) seemingly lowered intuitive use (as measured by increased cognitive effort, time spent, and errors). This study recommends that the image schemas with a higher degree of match can be retained for future design of the product, while reviewing and improving the image schemas that did not transfer in the way the designer intended. In addition, image schemas that were overwhelmingly identified by the majority of the participants, but not represented in the design, should be incorporated for future design of the product. The study also reveals that direct observation and think aloud are sufficient to be employed in identifying image schemas in future studies. Applying image schemas in an evaluative fashion in this study was a novel way of quantifying intuitive interaction. The methods used for the evaluation of this study can be generalised with minor modification as necessary to cover various multifunctional digital products for intuitive and usability testing. The strategy that has been developed could be applied easily to early prototyping.

The next chapter will address part of the issues identified while implementing the study's methodology. One of the key issues identified as a limitation to the approach was the application of different rules for image schema extraction by the independent evaluators recruited. This could affect the reliability of the extracted image schemas used for the evaluation, and it also increases the cost of implementing the approach. The next chapter focusses on addressing this problem by developing a knowledge-based approach for extracting image schemas from the users' utterances.

CHAPTER 6

AN ALGORITHM FOR EXTRACTING IMAGE SCHEMAS FROM USERS' UTTERANCES

In the previous empirical study conducted in Chapter 5, the complex nature of the attributes of image schemas was observed to have an effect on the reliability of the image schemas extracted by the independent evaluators. This problem was observed to be the bases upon which the independent evaluators provided justification for the image schemas extracted in the context of the users' utterances. This limitation could hamper the adoption of image schemas as a means for design and evaluation of the intuitive use of interfaces. This chapter addresses this limitation by proposing a systematic approach based on an algorithm for extracting image schemas from users' utterances. This developed structured approach addresses the difficulty in the system of extracting image schemas that is predominantly based on the personal expertise of the researchers involved. The algorithm utilises two ontologies: the lexical and the domain-specific (image schema ontology). The domain-specific ontology was purpose-built for the needs of the study. The identified image schemas were extracted based on a match between the lexical ontology and the domain-specific ontology developed for the study.

This chapter is divided into three sections. The first section describes the proposed algorithm for extracting image schemas from the users' transcribed utterances. The second section illustrates how the algorithm was used to extract image schemas based on the transcripts of the participants' utterances used in the previous studies (Studies 1 and 2). The third section describes the strategy developed for evaluating the algorithm, the evaluation results, and implications for design for intuitive use.

6.1 ONTOLOGIES

'Ontology' is the description of a conceptualisation. According to Guarino (1998), ontology is 'a logical theory accounting for the intended meaning of a vocabulary'. The present study proposes an algorithm for extracting image schemas from user-transcribed utterances based on two ontologies: the lexical and domain-specific ontologies developed for the study. The two ontologies were used as the knowledge base of the algorithm. The conceptualisation of the two ontologies with respect to their intended meaning used in the study is described below.

6.1.1 Lexical Ontology

The current study adopts OntoRo, a lexical resource based on *Roget's Thesaurus* (Davidson, 2003). One of the main advantages of *Roget's Thesaurus* (hereafter 'Roget's') is its unique ability to identify the different meanings of words based on different contexts (Setchi and Bouchard, 2010). OntoRo was developed for Roget's six levels of classifications, as shown in Table 6.1. This involves six classes of words, which are evenly divided into external and internal words, 39 sections, 95 subsections, and 990 concepts. Within these concepts, words and phrases are organised in 'semicolon' groups, which belong to either one of the four parts of speech (i.e. noun, adjective, verb, and adverb). Within each part of speech, there are separate paragraphs that link related words semantically.

Table 6.1: OntoRo Classification Based on *Roget's Thesaurus*

Classification	Meaning
Class	This is the top level of the structure. It is divided into six classes split into the internal and external world.
Section	This deal with particular aspects of the class to which it belongs. This is divided into 39 sections.
Subsection	These are a subset of the sections. They consist of 95 sections.
Concept	These are the heads consisting of 990 concepts.

Part of speech	These are the part of speech under each concept. The four major parts of speech include noun, verb, adjective and adverb
Paragraph	The words and phrases under each part of speech are divided into paragraphs.

OntoRo has been employed in several studies in the design field (Setchi and Bouchard, 2010; Setchi et al., 2011; Fadzli and Setchi, 2012). OntoRo was adopted in the current study as a knowledge source for the following reasons:

(1) Roget's unique ability to identify the meaning of words based on different contexts. The structural element that forms an image schema is more readily identified by Roget's compared to other lexical ontologies. For example, the *centre-periphery* image schema consists of an entity, a centre and a periphery. While WordNet (Princeton University, 2010) only identifies 'entity' in one sense as *existence*, Roget's identifies four possible senses: existence, substantiality, whole, and unity). 'Whole' in the context of image schemas captures the right sense of the application of the attributes of 'entity' as in *centre-periphery*.

(2) As observed by Clausner and Croft (1999), the Roget's entries parallel the relationship between the structural elements that form the image schemas' attributes. For example, the category of 'containment' found under the heading 'spatial state' corresponds to the 'boundedness' of a container image schema. The boundedness of space (represented by the boundary separating the interior from the exterior) is one of the structural properties that constitute the *container* image schema.

6.1.2 Domain-Specific Ontology

The lexical ontology in conjunction with the domain-specific ontology constitutes the knowledge base used in the algorithm that extracts image schemas from users' utterances. The existing classification of image schemas is based on two levels, comprising differing classes and categories (Johnson, 1987; Lakoff, 1999; Dodge and Lakoff, 2005; Langdon and Clarkson 2007; Hurtienne and Blessing, 2007). For example, image schemas are classified according to Langdon and Clarkson into seven classes and forty-one categories. The domain-specific ontology proposed in the current study was built as a three-level classification system comprising five classes, twenty categories, and forty properties.

Figure 6.1 shows the flowchart used to develop the ontology. The ontology consists of five classes (containment, force, space, multiplicity and attributes) and twenty categories of image schemas (Table 6.2). Previous reserachers has shown that image schemas from categories space and attributes are very useful in tangible interactions (Hurtienne et al, 2009; Hurtienne, 2011; Maracanas, 2012). The image schemas used in these two classes represents 50% (10 out of 20) of all image schemas encoded in the ontology.

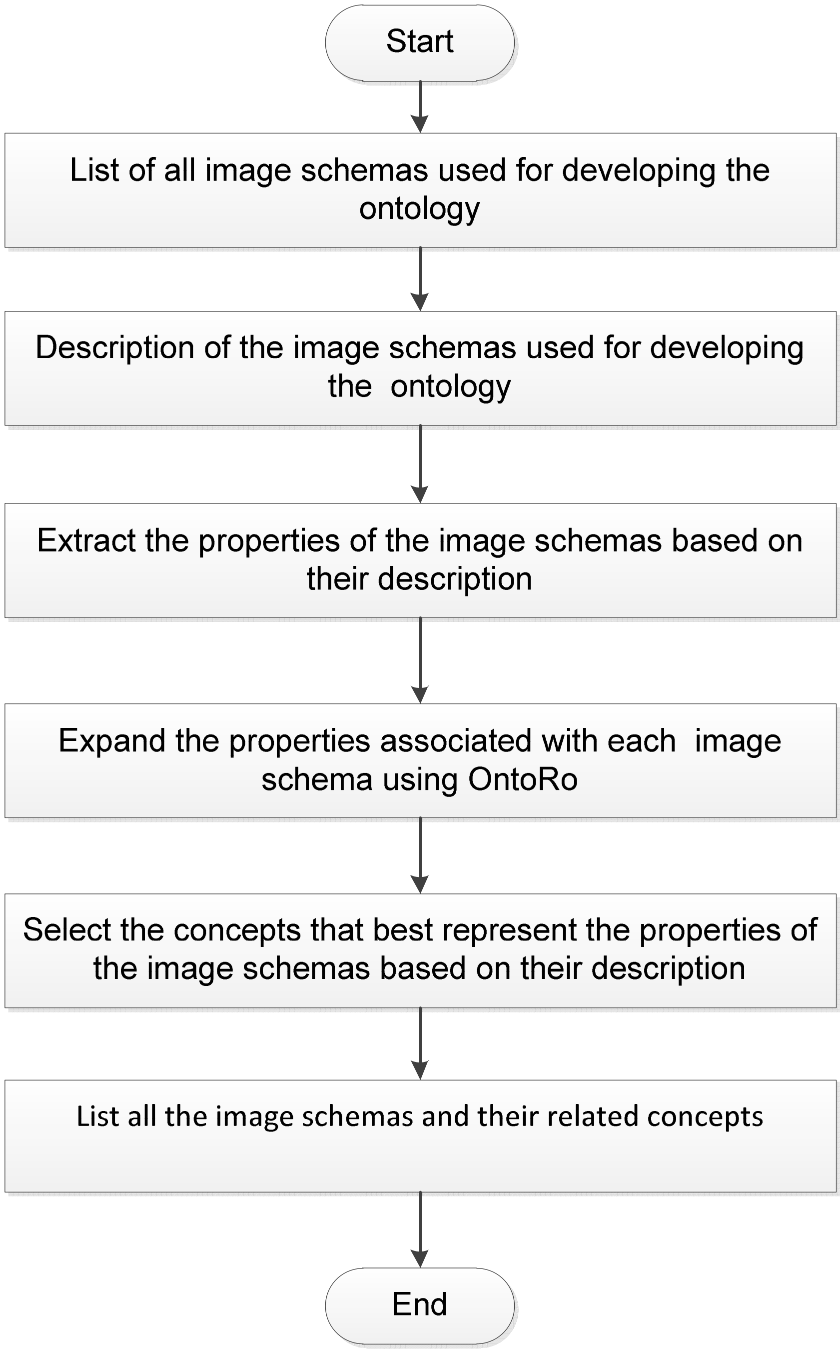


Fig 6.1: Flowchart for developing the image schema ontology

Table 6. 2: Image Schemas used for Developing the Ontology.

S/N	Image schema class	Image schema category
1	Containment	Container, Content, In-Out
2	Space	Centre-periphery, Contact, Front-back, Near-far, Path, Scale, Up-down, Rotation
3	Multiplicity	Matching, Link, Part-whole
4	Attribute	Big-small, Bright-dark
5	Force	Attraction, Compulsion, Blockage, Balance

The next step includes compiling the description of the twenty image schemas using previous work by several authors (Lakoff and Johnson, 1980; Johnson, 1987; Lakoff, 1987; Talmy, 1988a, b; Dodge and Lakoff, 2005; ISCAT, 2012) as shown in Table 6.3. The table (Table 6.3) contains five of the twenty image schemas used for developing the ontology. See Appendix G for the description of the twenty image schemas used for developing the ontology.

Next, the properties associated with each image schema were extracted from their description. For example, the image schema *container* consists of a *boundary* that separates an *interior* (space enclosed by the boundary) from the *exterior* (the surrounding area—space not enclosed by the boundary) and, often, a *portal* (an opening in the boundary that allows motion between the interior and the exterior) (Dodge and Lakoff, 2005). The *container* image schema belongs to the containment class, and has four properties based on its description: *interior, exterior, movement into*, and *movement out*. The properties of each of the image schemas were used for the third-level classification.

Table 6.3: Image Schema Description

Class	Categories	Definition	Structural properties
Containment	Container	A ***CONTAINER*** consists of a *Boundary* that separates an *Interior* (space enclosed by the Boundary) from the *Exterior* (the surrounding area - space not enclosed by the Boundary) and, often, a *Portal* (an opening in the Boundary that allows motion between the Interior and the Exterior) (Dodge and Lakoff, 2005)	Interior Exterior Movement into (Ingress) Movement out (Egress)
Space	Path	A ***PATH*** consists of a source or starting point, a goal or end-point, and a sequence of contiguous locations connecting the source with the goal (Johnson, 1987).	Source Goal Path
Multiplicity	Part- whole	***PART-WHOLE*** is an image schema that consists of a whole, parts, and a configuration (Lakeoff, 1987).	Whole Part Configuration
Attribute	Big- Small	**Big-Small** is conspicuous in position or importance, Significant (ISCAT, 2012).	Big Small
Force	Attraction	***ATTRACTION*** is a force image schema in which a (passive) object exerts a force on another object, either physically or metaphorically, to pull it toward itself (Johnson, 1987).	Attraction

Following that, each of the properties associated with the image schemas is expanded by listing all the related concepts using OntoRo. For example, the word ‘interior’, representing one of the properties of the *container* image schema, is linked to six concepts in OntoRo, representing intrinsicality (concept #5), component (concept #58), inclusion (concept #78), interiority (concept #224), land (concept #344), and painting (concept #553).

The next phase involves selecting the concepts that best describe the properties of the image schema. For example, of the six concepts that were identified in OntoRo to be associated with the container image schema, only interiority (concept #224) is related to the property of ‘interior’, which describes the concept as a space enclosed by a boundary. Each of the 990 concepts is labelled through its number in OntoRo, as well as the first word in the list of all the words and phrases belonging to the concept. For example, the concept #224 (*interiority*) is represented in OntoRo with 191 words, which describe different aspects of ‘interiority’. While some of these words properly describe the attribute of ‘interior’ as it relates to a space enclosed by the boundary, others are irrelevant to the description of the property. The same approach was applied to identifying the most relevant sense for the significant properties of each image schema analysed. As a result, ‘exterior’ was mapped to exteriority (concept #223), ‘movement into’ was related to ingress (concept #297), and ‘movement out’ was related to egress (concept #298), as shown in Table 6.4. The container image schema was used to illustrate how the ontology was developed in the table (Table 6.4). (See Appendix G for the twenty image schemas used for developing the algorithm.)

Interiority, interior, inside, indoors, inner surface, undersurface, endoderm, skin, sapwood, heartwood, wood, inmost being, heart's blood, soul, heart, centre, breast, bosom, centrality, inland, Midlands, heartland, hinterland, up-country, the nitty gritty, pith, marrow, substance, subsoil, substratum, base, permeation, pervasion, presence, interjacency, interspace, interval, deepness, cave, pit, pothole, penetralia, recesses, innermost recesses, depth, endogamy, marriage, introversion, intrinsicality, selfdbsorption, egoism, egotism, egocentrism, egocentricity, egomania, selfishness, introvert, egoist, ,egutist, inmate, indweller, Weller, internee, prisoner, insides, contents, inner man, inner woman, Interior man, internal organs, viscera, vitals, heart, ticker, lungs, lights, liver, kidneys, spleen, offal, meat, bowels, entrails, innards, guts, pluck, tripe, intestines, colon, und um, back passage, abdomen, belly, paunch, underbelly, womb, uterus, stomach, tummy, maw, chest, breast, bosom, solar plexus, gland, endocrine, cell, urganism, interior, internal, inward, intrinsic, inside, inner, innermost, midmost, central, inland, up-country, removed, domestic, home, vernacular, intimate, familiar, known, indoor, intramural, shut in, enclosed, inboard, built-in, inwrought, endemic, residing, deep-seated, deep-rooted, ingrown, fixed, intestinal, visceral, intravenous, subcutaneous, interstitial, interjacent, inwardlooking, introvert, intrinsic, endo-, endogamous, endogenous, be inside, be internal, be within, lie within, lie beneath, be at the bottom of, show through, be visible, hold within, hold, comprise, place within, embed, insert, keep inside, intern, imprison, enfold, embay, enclose, internalize, absorb, inside, within, in, deep in, deep down, inly, inwardly, intimately, deeply, profoundly, at heart, withinside, within doors, indoors, at home, en famille, chez, at the sign of.

Table 6.4 Domain-specific Ontology Showing the *Container* Image Schema

Class	Categories	Definition	Structural element	Concept in OntoRo	Relevant concept	Semantically related word
Containment	Container	A ***CONTAINER*** consists of a *Boundary* that separates an *Interior* (space enclosed by the Boundary) from the *Exterior* (the surrounding area - space not enclosed by the Boundary) and, often, a *Portal* (an opening in the Boundary that allows motion between the Interior and the Exterior) (Dodge and Lakoff, 2005)	Interior	5: Intrinsicality 58: Component 78: Inclusion 224: Interiority 344: Land 553: Painting	224: Interiority	interiority, interior, inside, indoors, inner surface, undersurface, endoderm, skin, sapwood, heartwood, wood, inmost being, heart's blood, soul, heart, centre, breast, bosom, centrality, inland, Midlands, heartland, hinterland, up-country, the nitty gritty, pith, marrow, substance, subsoil, substratum, base, permeation, pervasion, presence, interjacency, interspace, interval, deepness, cave, pit, pothole, penetralia, recesses, innermost recesses, depth, endogamy, marriage, introversion, intrinsicality, selfdbsorption, egoism, egotism, egocentrism, egocentricity, egomania, selfishness, introvert, egoist, egutist, inmate, indweller, Weller, internee, prisoner.
			Exterior	6: Extrinsicality 59:	223: Exteriority	exteriority, the external, outwardness, externality, surroundings, periphery,

				Extrenousness 223: Exteriority 445: Appearance 875: Ostentation:		circumference, sidelines, outline, exterior, outward, appearance, superficiality, surface, superficies, superstratum, crust, cortex, shell, integument, skin, outer side, face, facet, façade, front, other side, contraposition, externalism, regard for externals, idolatory, externalisation, extroversion, extrovert, extrisincality, outside, out of doors, open air, outer space, distance, extraterritoriality, exclusion, foreignness, extraneousness, eccentricity, nonconformity, outsider, nonconformist.
			Movement into (Ingress)	297: Ingress 305: Passage	297: Ingress	enter, turn into, go in, come in, move in, drive in, run in, breeze in, venture in, sidle in, step in, walk in, file in, follow in, come after, set foot in, cross the threshold, darken the doors, let onself in, unlock the door, turn the key, open, gain admittance, be invited, look in, drop in, pop in, blow in, call, visit, mount, board, get aboard, gd hop in, jump in, pile in, squeeze into, wedge onself into, pack oneself into, jam oneself into, creep in, slip in, edge

						in, slink in, sneak in, steal in, work one's way into, buy one's way into, insinuate oneself, worm into, bore into, pierce, bite into, eat into, cut into, notch, put one's foot in, tread in, fall into, drop into, tumble, sink into, plunge into, dive into, plunge, join, enlist in, enrol oneself, be one of, immigrate, settle in, place oneself,let in, admit, put in, insert, enter oneself, enter for, contend
			Movement out of (Egress)	296: Departure 298: Egress 305: Passage 46: Disunion 69: End 234: Edge	298: Egress	emerge, pop out, stick out, project, jut, pop one's head out, peep out, peer out, be visible, surface, break water, ascend, emanate, transpire, be disclosed, egress, issue, debouch, sally, make a sortie, issue forth, sally forth, come forth, go forth, issue out of, go out, come out, creep out, sneak out, march out, flounce out, fling out, walk, jump out, bale out, leap, clear out, evacuate, decamp, emigrate, travel, exit, walk off, depart, erupt, break out, break through, burst the bonds, escape, get the boot, get the bird, get the push, get the heave-ho.

Table 6.5 shows the classification table linking the image schemas to their related concepts in OntoRo.

The next section describes the algorithm for extracting image schemas from user's utterances.

Table 6.5: Image Schema Classification

S/N	Image schema classes	Image schemas categories	Related OntoRo concepts
1	Containment	Container	224, 223, 297, 298
2		Content	224
3		In-out	224, 223, 297, 298
4	Space	Centre-periphery	52, 225, 234
5		Contact	45
6		Front-back	237, 238
7		Near-far	199, 200
8		Path	68, 69, 624
9		Scale	27
10		Up-down	209, 210, 308, 309
11		Rotation	315
12	Multiplicity	Matching	18, 462
13		Link	47
14		Part-whole	52, 53, 58, 243
15	Attribute	Big-small	32, 33, 195, 196, 638, 639
16		Bright-dark	417, 418, 425
17	Force	Attraction	291
18		Compulsion	740
19		Blockage	702

20		Balance	28

6.2 ALGORITHM FOR EXTRACTING IMAGE SCHEMAS

The method developed for extracting image schemas from the transcribed utterances of the participants is described below. The entire process (Figure 6.2) is divided into four phases: speech-to-text transcription (pre-processing), semantic expansion of the task-related words or phrases in the utterances, classification (disambiguation) of the identified related concepts, and image schema extraction. The algorithm was implemented in C++. See Appendix H for the source code of the algorithm.

6.2.1 Speech-to-Text Transcription (Pre-processing)

The phase involves the transcription of the speech of the participant into text. The participants think aloud in study 1 was used in this phase. To reiterate, the task involves 42 participants completing the same set task with 3 different alarm clocks. The think aloud data was transcribed using express scribe and thereafter manually checked for accuracy. The summary table of the think aloud of the 42 participants is shown in Table 6.6. A total of eight thousand eight hundred and fifty words were recorded in the task using the 3 products. The table (Table 6.6) also shows the summary in terms of time and length of the words range for each product. For example, for product 1, the breakdown of the word range from 30 to 185 words, while the time range from 85 to 502 seconds.

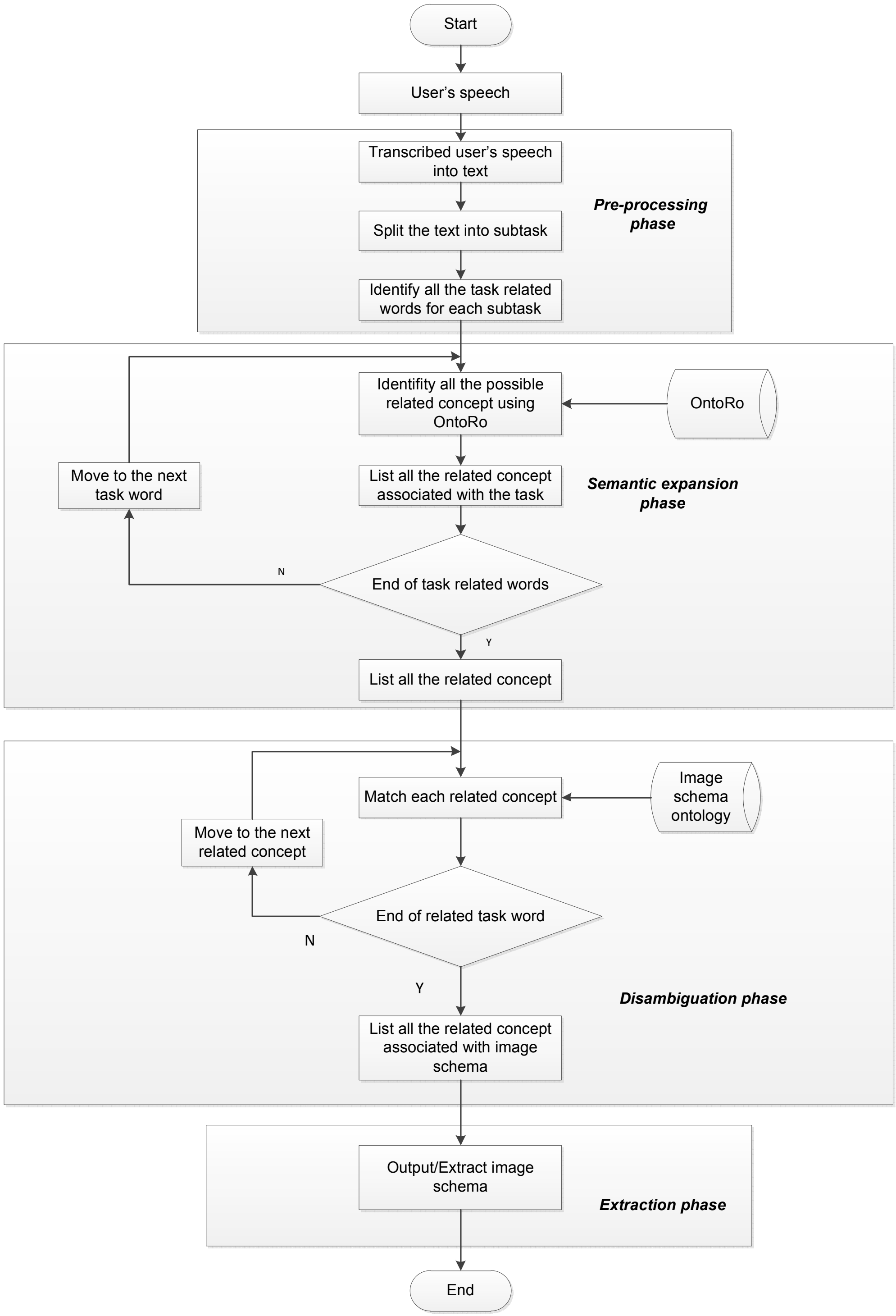


Figure 6.2: Algorithm for Extracting Image Schemas from Users’ Utterances

Table 6.6: Summary of the Transcript of the Participants Think Aloud Data

S/N	Product	Task duration (secs)		Number of words	
		Minimum	**Maximum**	**Minimum**	**Maximum**
1	Product 1	85	502	30	185
2	Product 2	34	396	27	162
3	Product 3	138	586	10	126

Thereafter, the transcript of the participants was split into different aspect of the subtasks using the interaction cycle developed for the task shown in Figure 5.4. Next, the task related words associated with each subtask is identified. The task related words are the keyword associated with the task. For example, a participant's transcript for the completion of subtask 1 is shown as follows: "I have to press this part to change the mode". The analysis of the task based on the task steps from the manual shows that to get into the alarm mode, one has to press the mode button. The mode button is inferred to mean this "part" as used by the participant while change can be inferred to mean moving from one mode (alarm mode) to another (time mode). In the example, the task related words comprise 'press', 'part', 'change', and 'mode', while the other words (I, have, to, this, the) are ignored. The process was used to identify all the tasks related words used by the participants in the study. The task related words used by the participants is semantically expanded in the next phase.

6.2.2 Semantic Expansions

The task related words and phrases used for completing the task are enriched by a process called semantic expansion. In this context, semantic expansion is the list of all possible senses corresponding to the task related words or phrases used in the interaction.

In the example used previously, ‘press’, ‘part’, ‘change’, and ‘mode’ were identified as the task related words. The expansion process starts by selecting the first task related word in the list (‘press’) and searching for all words, which are semanticaslly related to it, in OntoRo. This is conducted automatically as shown in the semantic expansion phase in the flowchart in Figure 6.2. For example, 16 concepts are identified in Ontoro as semantically related to the word ‘press’. This includes *crowd (*concept #74); *make smaller* (concept #198); *flattener* (concept #216); *be supported* (concept #218), *smooth* (concept #258); *impel* (concept #279); *weigh* (concept #322); *press* (concept #587); be *resolute* (concept #599); *incite* (concept #612); *activity* (concept #678); *advise* (concept #691); *compel* (concept #740); *request* (#761); *take away* (#786); *caress* (#889). The algorithm then moves to the next task related word (‘part’) and conducts the same expansion until all the task related words in the subtask is exhausted. The list in Table 6.7 represents all the semantically related words associated with the task related words based on the subtask. This list of all semantically related words is thereafter disambiguated in the next phase.

Table 6.7: Semantic Expansion of Task-related Words

Words	**No. of Concepts**	**Related Concept**
Press	16	74: *crowd*; 198: *make smaller*; 216: *flattener*; 218: *be supported*, 258: *smooth*; 279: *impel*; 322: *weigh*; 587: *press*; 599: *resolute*; 612: *incite*; 678: *acting*; 691: *advice*; 740: *compel*; 761: *request*; 786: *take away*; 889: *caress*.
Part	13	46: *disunite*; 53: *part*; 55: *incompleteness*; 58: *component*; 263: *open*; 294: *diverge*; 296: *depart*; 410: *melody*; 412: *vocal music*; 589: *reading matter*; 594: *acting*; 622: *function*; 783: *portion*.
Change	15	*15: differ; 19: make unlike; 131: middle age; 142: fitfulness; 143: change; 147: be turned to; 150: quid pro quo; 152: changeableness; 152: vary; 172: unproductiveness, 178: influence; 228: wear; 229: doff; 797: coinage; 797: money.*
Mode	6	7: *state*, 86: *numeration*, 410: *melody* (*concord*), 610: *habit*, 624:

		way, 848: *fashion* (*etiquette*).

6.2.3: Image Schema Classification (Disambiguation)

The semantically related concepts associated with the task related words are disambiguated using the image schema classification shown in Table 6.5. The classification involves narrowing the meaning by linking the properties of the image schemas to the concept number of all semantically related words identified in the task. This is conducted in order to identify the concepts that best describe or represent the most accurate sense of the word in the context of the interaction. This process is conducted automatically.

The process flow involved in the classification is shown in the disambiguation phase in Figure 6.2. The process starts by selecting each of the semantically related word associated with task word and matching it with the image schema ontology. If there is a match, it links the concept number to the task related word, otherwise it moves to the next semantically related word until the list of all the semantically related words associated with that particular task word is exhausted. For the previously used example, each of the 16 semantically related words associated with the task word ‘press’ is matched with the image schema ontology. For example, crowd (concept #74) representing the first semantically related word in the list is matched with the image schema ontology. There was no match, hence the algorithm moves to the next, which is ‘make smaller’ (concept #198). This process is repeated until the list of all the semantically related words is exhausted. Table 6.8 shows the sixteen semantically related words associated with the task word ‘press’. Only one match is identified as compel (concept #740). Consequently, the task related word ‘press’ is linked to concept #740.

Subsequently, #624 is linked to the task related word ‘mode’ and #53 is linked to the task related word ‘part’. No match was identified for the task related word ‘change’.

Table 6.8: Image Schema Classification of the Semantically Related Words

Task related word	**Related concept**	**Match**
Press	*Crowd (*concept #74)	No match
	Make smaller (concept #198)	No match
	Flattener (concept #216)	No match
	Be supported (concept #218)	No match
	Smooth (concept #258)	No match
	Impel (concept #279)	No match
	Weigh (concept #322)	No match
	Press (concept #587)	No match
	Resolute (concept #599)	No match
	Incite (concept #612)	No match
	Acting (concept #678)	No match
	Advice (concept #691)	No match
	Compel (concept #740)	Match: (concept #740)
	Request (#761)	No match
	T*ake away* (#786)	No match
	Caress (#889)	No match

6.2.4 Image Schema Extraction

Finally, the image schemas linked to the related concepts are extracted. This is conducted automatically. The algorithm extract the image schema associated with the concept number linked to the task related word. For the example used above, 'mode' is associated with concepts #624, and is extracted as *path*, 'press' is associated with concept #740, extracted as *compulsion*; 'part' is associated with concept #53, and extracted as *part-whole* image schema.

This section has presented the proposed algorithm for extracting image schemas from users' transcribed utterances and the ontology used for developing the knowledge base. The next section shows how the algorithm is evaluated using the transcripts collected from the previous studies (chapter 5).

6.3 EVALUATION OF THE ALGORITHM

The responses generated from the previously conducted empirical studies (Studies 1 and 2) were used to illustrate how the algorithm was used for extracting image schemas from users' transcribed utterances. To reiterate, the empirical study conducted involved 42 participants completing the same task with three different alarm clocks. Overall, 126 observations were recorded during the interaction. Participants in the study were given the task to set the alarm clock to 8.30 a.m. prior to the start of the study; the clock was in the 'normal' mode, with the time set for 3:00 a.m. During the study, participants were encouraged to verbalise their thoughts. The participants' verbal responses were recorded and later transcribed. The task consisted of a sequence of five subtasks for Product 1, three subtasks for Product 2, and two subtasks for Product 3. The transcript of one of the participants' responses for Product 1 is shown below:

> *I have to look at the component to understand it. I have to get into the 'alarm' mode. I press the 'mode' button. The bright writings on a white background are making it difficult to read. I press the 'set' button. Okay, I have to set the hour*
>
> *now. Press this button to set the time. Okay, I press 'set' again and then go with the 'up' button to increase the minute. Yea, I can see the match of the bell. Okay, I think it is done.*

The task is broken down into subtasks. For Product 1, the task was comprised of a sequence of five subtasks. The subtasks are listed below, as identified from the alarm clock documentation for Product 1.

(1) Activate the alarm mode

(2) Activate the set option

(3) Set the hour mark

(4) Set the minute mark

(5) Activate the set time

The transcript of the participants' responses was broken down into the different aspects of the subtasks using the interaction task flow developed in the previous chapter (shown in Figure 5.4). The interaction task flow enabled the experimenter to identify the users' responses based on each subtask. The task related words were identified from each subtask for the 3 products used in the study.

The task related word identified for the 3 products used in the current study was compared with the 10 percent of the participants think aloud used by the 2 independent evaluators in the previous study. Recall, the same transcript of the participant's think aloud used in the previous studies (studies 1 and 2) involving the independent evaluators was the same used in the current study. This was done in order to examine the inter rater reliability regarding the task related word associated with each subtasks used in the study. Table 6.9 shows the number of the task related words used by the 2 evaluators as well as the one used in the current study. The examination shows that all the task related words used by the independent evaluators was also identified and used in the current study. For example, out of the 14 task related words identified and used by the first independent evaluator, all was equally identified and used in the current study. See Appendix I for the list of the task related words used by the algorithm and the 2 independent evaluators for extracting image schemas in the study.

Table 6.9: Comparison of the Task related Words identified by the Evaluators

Product	Task related words identified		
	Current study	Evaluator 1	Evaluator 2
1	18	14	12
2	16	15	13
3	19	19	17

Following the method described in the previous section, the task-related words were identified as shown in Table 6.10. For example, the task related words associated with subtask 1 include 'component', 'get into', 'alarm', 'mode', 'press', and 'button'.

Table 6.10: Transcribed Utterances Broken into Subtasks

Subtask	Utterances	Task related words
Subtask 1 Activate the set time	I have to look at the component to understand it. I have to get into the 'alarm' mode. I press the 'mode' button	Component, get into, alarm, mode, press, button
Subtask 2 Activate the set option	The bright writings on a white background are making it difficult to read. I press 'set'	Bright, writings, white, background, read, press, set.
Subtask 3 Set the hour mark	Okay, I have to set the hour now. Press this button to set the time	Set, hour, press, button, time
Subtask 4 Set the minute mark	Then go with the 'up' button to increase the minute	Up, button, increase, minute
Subtask 5 Activate the set time	Okay, I press 'set' again. Yea, I can see the match of the bell	Press, set, match, bell

The task related words associated with the 5 subtasks was fed into the algorithm for processing. Following the same process described in the previous section, semantic expansion, classification (disambiguation) and the extraction of the image schemas was automatically done. Table 6.11 shows the image schema output of the algorithm for the participant used above. The table also shows the task related words with no match for any image schema.

Table 6.11: Image Schemas Extracted by the Algorithm

Participants	**Subtask**	**Task related word**	**Output from the algorithm**			**No match**
			Task related words	**Concept number**	**Image schemas**	
1	1	Component, get into, alarm, mode, press, button	Component Get into Mode Press	58 297 624 740	Part-whole Container Path Compulsion	Alarm, Button
	2	Bright, Writings, White, Background, Read, Press, Set.	Bright White Press Set	417,425 417 740 58	Bright-dark Bright-dark Compulsion Part-whole	Writings Background Read
	3	Set, hour, press, button, time	Set, Press	58 740	Part-whole Compulsion	Hour Button, Time
	4	Up, Button, Increase, minute	Up Increase	209, 308 308	Up-down Up-down	Button Minute
	5	Press, Set, Match, bell	Press	740	Compulsion	Bell

			Set Match	58 18,462	Part-whole Matching	

Having illustrated how the algorithm was applied for extracting image schemas from users' transcribed utterances, the next section will describes the strategy for evaluating the output of the algorithm.

6.4 EVALUATION RESULTS

The algorithm was evaluated based on the accuracy of the image schemas identified to be relevant for the task by experts with knowledge of image schema analysis. The image schemas extracted from the responses of the participant were considered accurate if the algorithm and the evaluators identified them to be relevant for the task, and inaccurate if otherwise. It is expected that there would be a high level of agreement in the image schema identified to be relevant for the task by the algorithm and the independent evaluators, irrespective of the extraction strategy adopted by the evaluators.

As mentioned earlier, the data from Studies 1 and 2 were used for the evaluation. The results of the experimenter and the two independent evaluators recruited for the independent study (Study 2) were compared to the number of image schemas extracted by the algorithm, as shown in Table 6.12. The evaluation of the image schemas extracted by the algorithm reveals that the following percentages were correctly extracted by the independent evaluators and the experimenter for the same task. For the first independent evaluator, 81.82 percent for Product 1, 66.67 percent for Product 2 and 3. The second evaluator correctly extracted 90.90 percent of the image schemas identified by the algorithm for the same task for Product 1, 61.53 percent for Product 2, and 76.92 percent for Product 3. Similarly, the experimenter accurately extracted 69.23 percent for product 1 and 2, while product 3, 70.58 percent.

Table 6.12 Comparison of the number of Image Schemas Extracted by the Experimenter and the Evaluators

Product	Algorithm and experimenter	Algorithm and first evaluator	Algorithm and second evaluator
	% agreement	% agreement	% agreement
1	69.23	81.82	90.00
2	69.23	66.67	61.53
3	70.58	66.67	76.92

Following that, the observed agreement of each image schema correctly identified as being relevant for the task by the independent evaluators and the experimenter was examined; for example, the number of times a particular image schema was correctly identified in all the subtasks. For example, the observed agreement of the evaluators on the use of the *container* image schema for the five subtasks in Product 1 was 57.14 percent. This means that 57.14 times out of 100, the evaluators identified the *container* image schema as being relevant for the task. The observed agreement of the image schemas extracted by the evaluators identified to be relevant for the completion of all the subtasks was computed as shown in Table 6.13. Thereafter, the strength of agreement of each image schema identified to be used for the task by the algorithm and the two independent evaluators was computed using Eq. 5.1. Chance agreement was taken to be 50 percent, since two options were possible for the independent evaluators: either an agreement or disagreement with the image schemas identified by the algorithm for the completion of the task. An agreement indicated that the relevant image schemas were correctly extracted for the task, while a disagreement showed that the image schemas were not relevant to the task, and thus incorrectly extracted.

The results revealed that product 1 had two image schemas with k value of less 0.6, three image schemas were observed to have a *k* value less than 0.6 for Product 2; while four image schemas had a *k* value less than 0.6 for Product 3. The overall strength value was substantial, with overall k value of 0.67 across the 3 products used in the study. Considering that chance agreement was taken into consideration, these results reveal a substantial level of accuracy of the image schemas identified for all the subtasks by the algorithm. This result demonstrates the utility of the developed algorithm, and could be used as an enhanced approach for extracting image schema from user's transcribed utterances.

Table 6.13: Evaluation of Image Schemas Extracted at Subtask level using Cohen kappa, k.

Image schemas	Product 1		Product 2		Product 3	
	Observed agreement of the evaluators	**k**	**Observed agreement of the evaluators**	**k**	**Observed agreement of the evaluators**	**k**
Container	57.14	0.15	85.00	0.71	0.00	0.00
Content	100.00	1.00	100.00	1.00	0.00	0.00
Attraction	0.00	0.00	33.00	0.34	0.00	0.00
Bright-dark	100.00	1.00	100.00	1.00	0.00	0.00
Compulsion	100.00	1.00	100.00	1.00	100.00	1.00
Centre-periphery.	-	-	-	-	-	-
Matching	100.00	1.00	0.00	0.00	82.67	0.67
Path	100.00	1.00	0.00	0.00	100.00	1.00
Up-down	100.00	1.00	100.00	1.00	100.00	1.00
Rotation	-	-	-	-	100.00	1.00
Front-back	-	-	-	-	100.00	1.00
Part-whole	100.00	1.00	100.00	1.00	-	-

6.5 DISCUSSION

The strategy adopted by the evaluators based on the task-related words or phrases from which image schema was identified shows a similar pattern with the approach used in the study. Table 6.14 shows the task related words used for extracting image schema from the users' transcripts, both for the algorithm, the experimenter and the two evaluators. For example, for the completion of the task using Product 1, twenty-nine task-related words or phrases were pre-processed for extracting image schemas in the current study. These 29 task related words contains all the task related words used by the experimenter, and 2 independent evaluators in the previous study. The number of the task related words that matches an image schema in the algorithm was compared with the task related words from which image schemas were extracted by the experimenter and 2 independent evaluators. For the experimenter, 82.75 percent of identical words or phrases used in the study returned a match for product 1, 74.07 percent for product 2, and 80.00 percent for product 3. The evaluation of the words or phrases by the first evaluator showed that 78.57 percent of identical words were correctly matched in the context of the task for Product 1 in accordance with the algorithm, 53.33 percent for Product 2, and 63.15 percent for Product 3. For the second independent evaluator, 66.67 percent of identical words or phrases used in the study were observed for Product 1, 53.84 percent for Product 2, and 58.82 percent for Product 3. The words or phrases used by the evaluators as the basis for extracting the image schemas employed for the task showed a substantial level of agreement with the algorithm. These results indicate that the task-related words in the context of the users' transcripts were mostly used as a strategy for identifying the image schemas relevant for the completion of the task.

Table 6.14: Number of Task Related Words Identified in the Study

Product	Algorithm	Experimenter	
		Match	No match
1	29	24	5
2	27	20	7
3	30	24	6
Product	**Algorithm**	**Evaluator 1**	
		Match	**No match**
1	18	11	3
2	16	8	7
3	19	12	7
	Algorithm	**Evaluator 2**	
		Match	**No match**
1	18	8	4
2	16	7	6
3	19	10	7

In the same vein, the analysis of the image schemas extracted from the same identical words or phrases used in the context of the task by the algorithm and the evaluators was examined. For example, a task related word 'clockwise' identified in the study was extracted as rotation image schema by the algorithm, while the evaluators extracted it as cycle image schema. The results revealed that 76.32 percent of the image schemas were correctly extracted from the same identical words related to the task for Product 1, in accordance with the algorithm; 84.62 percent for Product 2; and 82.75 percent for Product 3. These identical words or phrases were considered by the evaluators to be the most appropriate representation of the image schemas used in the context of the interactions. These results suggest that the approach employed for identifying the words or phrases from which the image schemas were extracted shows a high level of agreement based on human expert judgement.

6.6 SUMMARY

This chapter presented the proposed algorithm for evaluating image schemas from users' utterances. The algorithm was illustrated with the transcripts of the participants think aloud protocols, involving 126 observations. The evaluation results show a substantial level of agreement based on the image schema identified to be relevant for the task. It is interesting to note that the evaluators were able to reach similar conclusions with the algorithm about the image schemas, which is relevant in the context of the task.

Furthermore, the study also revealed the utility of using the algorithm for image schema extraction; this is preferable to relying on the expertise of experiment conductors, which is susceptible to subjective bias. The algorithm supports the extraction of image schemas from users' utterances. The evaluation shows that the algorithm substantially identified and extracted image schemas accurately compared to expert human judgement.

Although the algorithm developed does have some limitations, as observed during the study, the issues observed were generally related to the number of image schemas used for developing the knowledge base. The ontology that was employed as the knowledge base of the algorithm was developed for twenty image schemas, covering a substantial part of the image schemas useful for tangible interaction. There were a few cases where the image schema was identified by one of the evaluators but was not represented in the algorithm. Consequently, the image schema was not identified by the algorithm. This aspect of the problem could easily be addressed by increasing the number of image schemas used in developing the ontology, and testing resulting ontology across a wide range of products in future studies. Overall, the image schema extraction based on the algorithm showed great results as compared to human expert judgement.

Having shown the advantages of using the developed algorithm for image schemas extraction, the next chapter will employ the algorithm as part of the approach for addressing the evaluation of the affective aspect of intuitive use in products.

CHAPTER 7

EVALUATING THE AFFECTIVE ASPECTS OF INTUITIVE USE

Chapter 7 addresses the affective aspect of intuitive use based on image schemas. The approach used in the current study was developed from the utterances of the participants. It consists of the algorithm developed in Chapter 6 and a means of identifying the affective state of the user based on the words used to describe the interaction. The proposed approach is built on the assumption that humans are aware to some extent of their emotional state, and are able to describe their emotions (Mehrabian, 1995). The approach is then incorporated into the conceptual framework developed earlier, and used as a means for evaluating the affective aspect of the intuitive use of interfaces.

This chapter is divided into three sections. Section 1 describes the approach used for identifying the affective state of the user, and shows how the approach fits into the conceptual framework developed in Chapter 4. Section 2 discusses the empirical study conducted, to illustrate how the approach is employed for evaluating the affective aspect of intuitive use. Section 3 discusses the results and findings from the study.

7.1 PROPOSED APPROACH

The approach consists of a novel algorithm developed to extract the image schemas employed to complete a task, and a sentiment analysis conducted in order to determine the polarity of the affective words linked to the image schemas used in the task.

The utterances of the participants are recorded during interactions and then transcribed; the transcribed utterances are then pre-processed. This involved identifying from the statement (i) affect-related words used to describe the image schemas employed in the interaction, and (ii) task-related words from which image schemas are extracted; the remainder are ignored. Table

7.1 shows the process flow for identifying the affective words linked to the image schemas employed for the task. The process flow includes a tool for determining the affective words, and a novel algorithm (developed in Chapter 6) for extracting image schemas from the task-related words.

For example, the utterance '*The use of the "down" button to increase the time seems weird*' was extracted from a participant's 'think-aloud' while conducting the study. The quote contains the word 'weird', which describes the experience of using the image schema employed in the interaction, and the phrase 'down to increase', indicating the task-related words from which image schemas were extracted.

7.1.1 Affective Words

The first aspect of the pre-processed text uses the keyword spotting approach for identifying the affective words used in the interaction. The affective words reflected the users' personal experience of the use of the image schemas employed for the task. Then, a sentiment analysis is conducted on the affective words in order to classify the words into positive, negative, and neutral valences. A positive valence is evoked as a consequence of a positive evaluation of the situation, and vice versa. The identified affect word is categorised based on GALC.

For the example used above ('*The use of the "down" button to increase the time seems weird*'), 'weird' in this context reflects the user's personal experience or sentiment based on the image schema identified to be used for the completion of the task. The affect word 'weird' belongs to the category 'surprise', and based on GALC is classified as having negative valence.

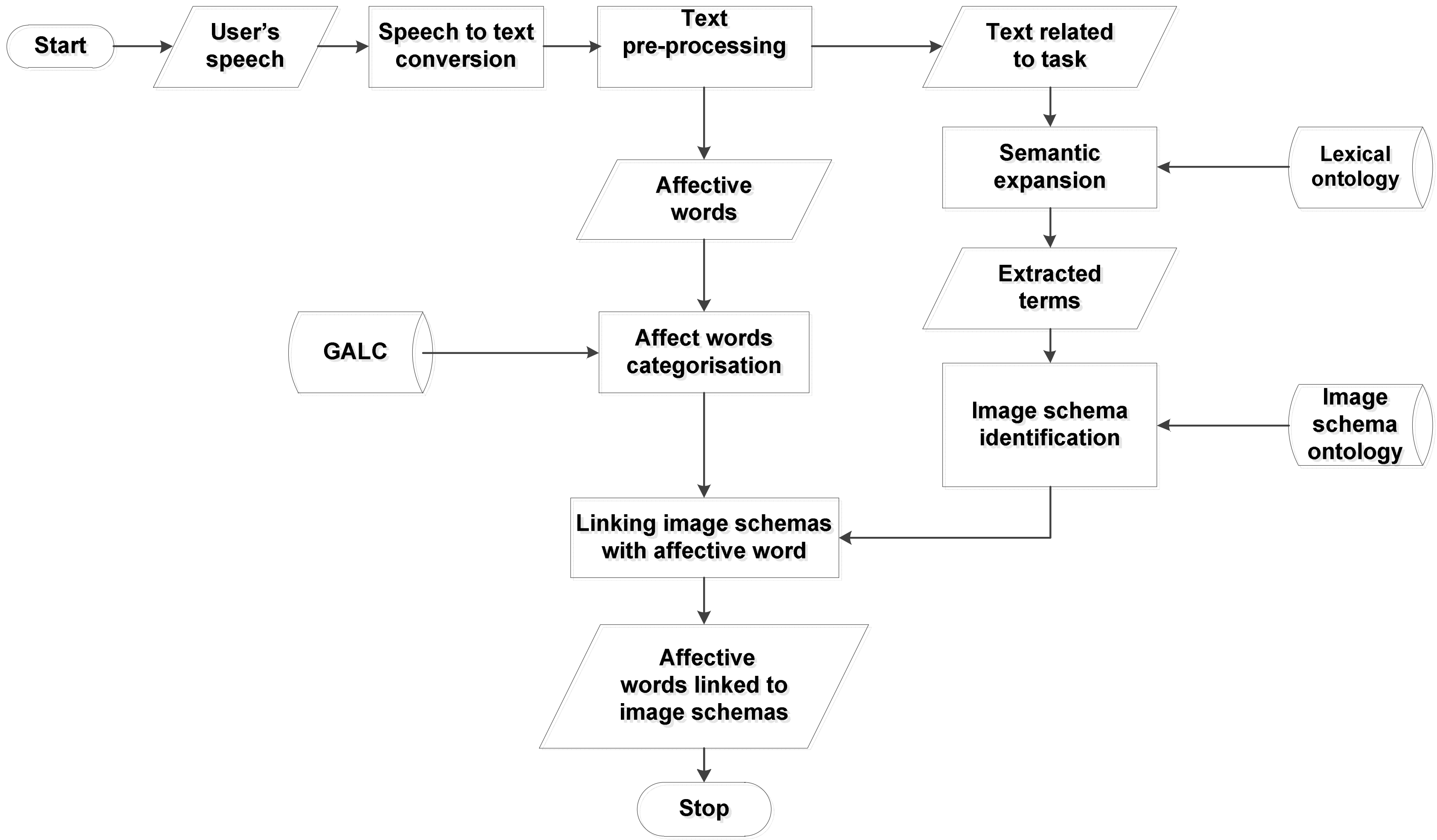


Figure 7.1: Process Flow for Identifying the Affective Words Linked to the image schemas used for the interaction

7.1.2 Task-related Words

The second part of the pre-processed text corresponding to the task-related words or phrases is fed into the algorithm that extract image schemas from the transcribed utterances of the users'. The extraction procedure was described in Chapter 6. The image schemas identified are extracted based on a match between the lexical ontology and the domain-specific ontology (image schema ontology) developed for the study. For the example used above, increase is associated with concept #309, and is linked to the *up-down* image schema.

The developed approach for linking the affective words to the image schemas used for the interaction is thereafter incorporated into the conceptual framework and used as part of the evaluation of the affective aspect of the intuitive use of interfaces. As shown in Figure 7.2, the approach involves goal identification, image schema extraction, analysis, and evaluation. Unlike in the previous approach, where the extraction of the image schemas was done manually, this new approach employed the developed algorithm for extracting the image schemas from the users' utterances. In addition, the means of identifying the affective words is also used as part of the evaluation process.

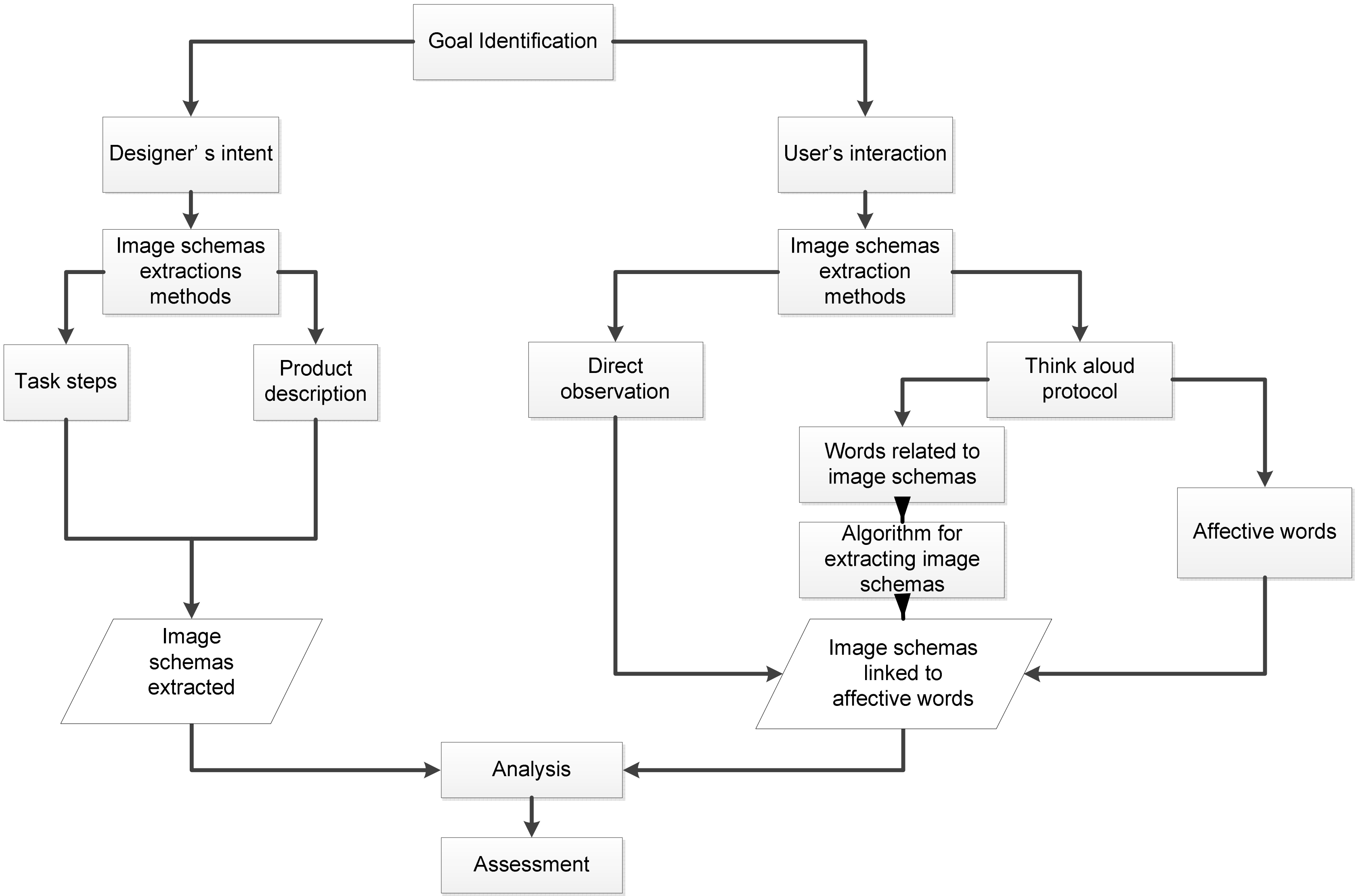


Figure 7.2: Conceptual Framework with the Affective Approach Incorporated

7.2 STUDY DESIGN

The proposed approach was evaluated through an empirical study involving forty participants completing a set task with two alarm clocks. The study was designed to (i) illustrate how the proposed approach was used to evaluate the affective aspect of intuitive use with products, and (ii) to test the validity of the proposed approach as a means for evaluating the affective aspect of intuitive use. Overall, eighty observations were recorded. The forty participants recruited for the study included 13 females (ages 23 to 38) and 27 males (ages 24 to 39).

The equipment used for the experiment included:

1) Four digital cameras, which recorded participants' interactions from four angles;
2) Noldus Observer XT software, which is software for capturing, analysing, and presenting behavioural data (Noldus, 2010);

The participants in the user study were given a task to set the time to 11.30 a.m. They were encouraged to verbalise their thoughts while interacting with the product. The task consisted of a sequence of three subtasks for Product 1, and five for Product 2. Prior to the start of the experiment, the clock was in 'alarm' mode, with the time set for 5.00 a.m. The participants were timed and observed during the task; all interactions were video-recorded. Figure 7.3 shows Product 1 used in the study. A structured questionnaire was completed by the participants immediately after the completion of the task. The study lasted approximately 30 minutes per participant.

Figure 7.3: Product 1 used in the Study

7.3 EVALUATION OF THE APPROACH

The procedure adopted for evaluating the affective aspect of intuitive use of the product based on the approach is described below. This follows the phases of the product evaluation proposed in Chapter 4.

A. Goal identification

As mentioned earlier in the description of the conceptual framework in chapter 4, the data extracted from the task steps and product descriptions from the product documentation were used as a proxy to represent the designer's intent. Table 7.1 shows task steps and product descriptions for the three subtasks for Product 1. The design of the clock consists of one display at the front, and five buttons, consisting of alarm, time, hour, minutes, and snooze, located at the top of the product. In addition, an alarm switch is located at the left side of the product. To set the normal time, the user must switch to 'time' mode and then press the alarm switch up to toggle between the alarm and time modes. Pressing the switch in the 'up' direction indicates the time mode, while 'down' indicates the alarm mode. The time mode has a 'dot' sign on the left side of the screen. To set the hour, the user must hold the alarm button down while pressing the minutes button from 5 to 11 a.m. Similarly, to set the minutes, the user holds the alarm button while pressing the minutes button from 0 to 30.

Table 7.1: Task Steps and Feature Description for Product 1 (Designer's Intent)

Task step	**Knowledge required to execute task step**	**Feature description**
Activate the time mode	Press the alarm switch up to enter time mode	The alarm switch is located at the left side of the product. The time mode environment is displayed on the top left corner of the screen with a dot sign
Set the hour	Hold the time button down, and press the hour button until it gets to 11 am	The time and the hour button are located at the top of the product. For each press, the number controlling the hour incrementally changes until 11 is displayed on the screen.
Set the minutes	Hold the time button down, and press the minutes button until it gets to 30	The time and the minute's button are located at the top of the product. For each press, the number controlling the minutes incrementally changes until 30 is displayed on the screen.

The users' interactions were recorded using the two methods mentioned earlier (direct observation and think aloud protocol), as shown in Table 7.2. The transcript of the think aloud protocol and direct observation of a participant while completing the task for subtask 1 was recorded for Product 1.

Table 7.2: Data Extracted from Users' Interactions with Product 1

Subtask	Direct observation	Think aloud protocol
Activate the time mode	The participant was observed to search for the switch controlling the time and alarm mode and pushed the switch forward. The participant was observed to examine the content of the screen to see if there is an indication of the time mode.	*'I have to search carefully to know where to begin. The arrangement of the feature is lovely. Okay. I have seen the switch. I have to press the switch forward to move into "time" mode. I can't really see anything that represents "time" mode. This is unexpected'.*
Set the hour	The participant was observed to try out different buttons as well as different combinations, occasionally looking at the screen to see if there was a change.	*'I have pressed almost all the buttons and nothing seems to be changing. This is very difficult. Aha, okay, I got it. You will need to hold the alarm and press the hour to set the hour to 11'.*
Set the minutes	The participant was observed to search for the time and the minute buttons. Repeated the same procedure as in the previous subtask.	*'The minute is quite simple to set. Hold the time and press the minutes until it gets to 30'.*

B. Image Schema Extractions

Next, the methods of extracting the image schemas corresponding to the designer's intent and the users' interaction were applied to the task identified in the task identification phase.

Following the same approach used previously in Chapter 5, *compulsion, path*, and *container* image schemas were extracted from the task steps; *part-whole* and *matching* were extracted from the product description, as shown in Table 7.3. The image schemas extracted corresponded to the designer's intent.

Table 7.3: Image Schemas Extracted from the Designer's Intent for Subtask 1

Quote	Image schemas	Justification
<u>Task step</u> Press the alarm switch to enter time mode	Compulsion Path Container	The compulsion image schema is extracted from the action word 'push'. The external force in the form of the users physically pushing the button causes the passive entity (alarm clock) to move from the alarm mode to the time mode. The *path* image schema is extracted from the movement along a path initiated by the force involving a push. The structural component of the path consists of a starting point, and end point and a path linking the start point to the end point. The alarm mode corresponds to the start point; the action 'push' initiates a movement along a path to the end point which is the normal mode. The *container* image schema is extracted from the word 'enter'. The normal mode represents the location out of the container; the action word 'press' initiates a movement through the portal into the container which represent the alarm mode. The *in-out* image schema is conceptualised from the container image schema as it relates to the location and movement in and out of a container.
<u>Feature description</u> The time mode environment is displayed on the top left corner of the screen with a dot sign.	Part-whole Matching	The central location of the screen creates spatial relationship with other features. The screen represents the part of the whole configuration. The dot symbol was used to represent the time mode. This was very difficult as participant made no meaning of what it represents in the context of the interaction.

The image schemas extracted from the users' interaction employed two methods, direct observation and think aloud protocol, as shown in Table 7.4. An observation of a participant while trying to complete the task shows the search pattern for the symbol used to represent the time mode that instantiates the *matching* image schema. Similarly, compulsion, *path*, and *container* image schemas were employed for the completion of subtask 1 based on the direct observation of the user.

Table 7.4 Image Schemas Extracted from Direct Observation

Task steps	Image schema	Justification
The participant was observed to search for the switch controlling the time and alarm mode and pushed the switch forward. The participant was observed to examine the content of the screen if there is an indication of the time mode.	Compulsion Path	The compulsion image schema is extracted from the force action 'push'. All force image schemas are related to path image schema as force interaction causes a movement along a path (Pena, 1999)
	Container	The screen activates the container image schema. The screen is seen as a space enclosed by a boundary separating the interior from the exterior (Johnson, 1987).
	Matching	The dots sign was used to represent the time mode environment. This aspect of the interaction was difficult for the majority of the participants to relate with.

Furthermore, the participants' utterances were recorded while interacting with the interface and later transcribed. The responses of one of the participants are shown below:

> *'I have to search carefully to know where to begin. The arrangement of the feature is lovely. Okay. I have seen the switch. I have to press the switch forward to move into "time" mode. I can't really see anything that represents "time" mode. This is unexpected'. 'I have pressed almost all the buttons and nothing seems to be changing. This is very difficult. Aha, okay, I got it. You will need to hold the alarm and press the hour to set the hour to 11'. 'The minute is quite simple to set. Hold the time and press the minutes until it gets to 30'.*

Table 7.5: Breakdown of the Participants' Responses for Subtask 1

Subtask	**Activity**	**Task-related word**	**Affective Words used to describe image schema**
Subtask 1 Activate the set time	I have to search carefully to know where to begin. The arrangement of the feature is lovely.	*Arrangement* of the feature	Lovely
	Okay. I have seen the switch. I have to press the switch forward to move in to time mode.	*Press* the switch forward to move *in* to time *mode*	-
	I can't really see anything that represents time mode. This is unexpected	*Represents* time mode	unexpected

In the first instance, the transcript of the participant's responses was split into the different aspects of the subtask task. The breakdown of the responses of the participant quoted above is shown in Table 7.5.

For Product 1, the task was comprised of a sequence of three subtasks. The subtasks included: activate the 'time' mode, set the hour, and set the minutes. The first paragraph of the user's responses corresponds to the first subtask for Product 1.

Thereafter, the affective words were identified from the transcript of each subtask using the keyword spotting approach, as shown in Table 7.6. For this participant, distinguishing between the 'normal' time and the 'alarm' mode, which represented the *matching* image schema, appears to have had a negative impact on the participant, based on the affect word 'unexpected' that the participant used to describe the interaction. In contrast, the arrangement of the feature that represents the *part-whole* image schema was described positively as 'lovely' by the participant. For the *compulsion, path*, and *container* image schemas, no affective word was used to describe the image schemas. (See Appendix I for the task-related words and phrases from which image schemas were extracted and their affective experience for the two products used in the study.)

Following that, sentiment analysis was conducted in order to determine the valence of the affective words using GALC. For example, the affect word 'lovely' was categorised according to GALC as pleasure/enjoyment and given a positive valence, while 'weird' was categorised as surprise and given a negative valence.

The sentiments linked to the image schemas identified to be used for the interaction were collated for all the participants across the two products used in the study. (Appendix J shows the list of the sixty-five affect-related words identified to be used in the study.)

Table 7.6: Image Schemas and the Affective Words Used for the Interaction

Words	Image schemas	Affective words	Sentiment analysis
Arrangement	Part-whole	Lovely	Positive
Press	Compulsion	-	-
Move in	Container	-	-
Mode	Path	-	-
Represent	Matching	Weird	Negative

Next, the task-related words and phrases were identified following the same approach described in the previous section, as shown in Table 7.5. The task related words and phrases were fed into the algorithm from which *part-whole, compulsion, container, path and matching* image schemas were extracted as shown in Table 7.7. Thereafter, the image schemas extracted, both from the designer's intent and the users' interaction in the study, were analysed in the next phase (image schema analysis).

Table 7.7: Image Schemas Extracted by the Algorithm

Participant	**Subtask**	**Task related word**	**Output from the algorithm**			**No match**
			Task related words	**Concept number**	**Image schemas**	
1	1	Arrangement Press Move in Mode Represent	Arrangement Press Move in Mode Represent	53 740 297 624 18	Part-whole Compulsion Container Path Matching	

C. Image Schemas Analysis

The image schemas used, and their categories, were identified from each subtask based on the coding developed for the study in Table 4.1. For subtask 1, Table 7.8 shows the method used in determining the image schemas appearing in the categories. For example, the users' behaviour on the use of the icon employed in the design to distinguish the 'normal' time from the 'alarm' time was examined. The 'dot' symbol was used as an icon to represent the 'normal' time mode, instantiating the *matching* image schema. The observation of the user while interacting with the products revealed that the participants searched for the icon used for representing the mode. The 'dot' symbol used by the designer to represent the time mode clearly made no sense to the users. The matching *image* schema was thus coded as being identified but incorrectly used in accordance with the designer's intent. The image schemas appearing in the three categories were then collated for the two products used in the study.

Table 7.8: Image Schema Analysis

Image schema	**Designer's intent**	**User interaction**	**Categories**
Matching	The 'dot' symbol was used as feedback … to represent the 'time' mode	During the interaction, the participant actually searched for the icon that represents the 'time' mode, both from direct observation and think aloud protocol. Its expectation was not met.	Though the participant actually searched for feedback in the form of a symbol to reassure him that he was in the 'time' mode (instantiating the *matching* image schema), his knowledge did not match what was represented in the design. Consequently, the matching image schema was categorised as *identified, but incorrectly used.*
Compulsion	The pressing of the switch was used to change between the time and alarm mode.	The participant actually displayed his knowledge in this domain based on the direct observation and his think aloud while completing the aspect of subtask 1: 'I have to press this switch … to move in to	There appears to be a match between the knowledge represented in the design and the actual knowledge required to execute the interaction. Hence, the *compulsion* image schema representing the press action is categorised as

		'alarm mode'.	*identified and correctly used.*

D. Image schemas assessment

The final phase involved the quantitative and qualitative assessment of the analysed image schemas from the previous phase. The image schemas employed for the completion of subtask 1 by a participant were computed as follows. The subtask required the use of five image schemas for executing the interaction. The quantitative assessment revealed that four image schemas were correctly used in accordance with the designer's intent (Category 1); one image schema was observed to be incorrectly used (Category 2) by the participant while completing the subtask. Using equation (4.1), with p=1, intuitive interaction was quantified as 80.00 percent for the subtask by the participant. The same procedure was used to compute for the other two subtasks. The Q value computed for all the participants is displayed in Table 7.9. (See Appendix L for the Q value computed for each image schema used for the task.)

Table 7.9: Quantification 'Q' Value Used by all Participants in the Study

	Product 1				**Product 2**			
	Category 1	Category 2	Category 3	Q value	Category 1	Category 2	Category 3	Q value
1	5	1	2	0.625	2	-	6	0.500
2	2	3	3	0.250	2	1	5	0.500
3	5	-	3	0.625	1	2	5	0.125
4	4	1	3	0.500	1	2	5	0.125
5	5	-	3	0.500	2	2	4	0.500
6	3	2	5	0.375	5	-	3	0.625
7	4	2	2	0.500	2	-	6	0.250

8	2	2	4	0.250	2	1	5	0.250
9	4	-	4	0.500	2	-	6	0.250
10	4	2	2	0.500	2	2	4	0.250
11	2	2	4	0.250	1	1	6	0.125
12	3	2	3	0.374	2	-	6	0.250
13	2	1	5	0.250	2	-	6	0.250
14	1	2	5	0.125	1	-	7	0.125
15	2	-	6	0.250	3	-	5	0.375
16	3	1	4	0.375	2	-	6	0.500
17	3	-	5	0.375	1	-	7	0.125
18	2	2	4	0.250	1	-	7	0.125
19	3	-	5	0.375	1	-	7	0.125
20	4	1	3	0.500	2	-	6	0.250
21	3	3	5	0.375	2	-	6	0.250
22	2	1	5	0.500	2	-	6	0.250
23	3	-	5	0.375	2	-	6	0.250
24	1	-	7	0.125	1	-	7	0.125
25	3	1	4	0.375	1	-	7	0.125
26	4	-	4	0.500	1	-	7	0.125
27	5	-	3	0.625	1	1	6	0.125
28	3	2	3	0.375	1	-	7	0.125
29	3	1	4	0.375	1	1	6	0.125
30	1	2	5	0.125	1	-	7	0.125
31	2	2	4	0.250	-	-	-	-
32	2	1	5	0.250	1	-	7	0.125
33	4	-	4	0.500	3	-	5	0.375
34	5	1	2	0.625	1	1	6	0.125

35	2	1	5	0.250	3	-	5	0.375
36	2	1	5	0.250	1	-	7	0.125
37	2	2	4	0.250	2	-	6	0.500
38	2	1	5	0.250	1	-	7	0.125
39	3	2	5	0.375	2	-	6	0.250
40	5	2	1	0.625	2	-	6	0.250

7.4 EVALUATION RESULTS

As mentioned earlier, the quantitative evaluation of intuitive interaction for the study is based on equation (4.1). It is expected that as the ‘Q’ value (the approach used for measuring intuitive interactions in the study) increases, the chances that participants will express more positive sentiments to describe the image schemas used for the interactions will increase, as well. Previous research has found that a positive type of emotional response is indeed correlated to intuitive preferences (Sinclair et al., 2002). In other words, a positive affective state activates intuitive processing.

To test this hypothesis, participants who successfully completed the task were grouped using the ‘Q’ value scores. Table 7.10 shows the participants ‘Q’ value that successfully completed the task. The ‘Q’ values of the participants were ranked in ascending order and then split into three groups comprising low, medium and high based on the ranking. The Q value was used as the independent variable in the study.

It is expected that ‘Q’ values of the participants will vary based on the familiarity of some of the product features used in the current study with other product features used in the past. For example, some participants were familiar with a simple touch to get into the menu for product 1, while others feel combining two buttons to get into the same menu for product 2 is quite demanding. Based on the two interaction style in the above examples of the two products used in the study, the ‘Q’ value of the participants is expected to vary based on the interaction style they are familiar with.

Table 7.10: Quantification ‘Q’ Value Used by Participants that successfully completed the task

Participants	‘Q’ Values computed for the participants	
	Product 1	Product 2
1	0.37	0.25
2	0.25	0.25
3	0.62	0.37
4	0.50	0.25
5	0.37	0.37
6	0.50	0.62
7	0.25	0.50
8	0.50	0.25
9	0.50	0.12
10	0.25	0.25
11	0.25	0.25
12	0.12	0.25
13	0.25	0.12
14	0.37	0.12
15	0.25	0.37
16	0.37	0.12
17	0.50	0.25
18	0.37	0.12
19	0.37	0.37
20	0.37	0.37
21	0.62	0.12
22	0.25	0.12
23	0.37	0.12
24	0.62	0.37
25	0.25	0.37
26	0.25	0.25
27	0.62.	0.37
28		0.2.5
29		0.12
30		0.50

Next, statistical analysis was conducted in order to determine if there were significant differences in the numbers of positive sentiments expressed in describing the image schemas employed for the interactions in the three groups (low, medium, and high). The mean and standard deviation number of affective words used for the interaction were computed for the two products used in the study, as shown in Table 7.11.

Table 7.11: Mean and Standard Deviation Sentiments Expressed in the Three Groups

	Variable	No.	Quantification Low		Quantification Medium		Quantification High	
			Mean	SD	Mean	SD	Mean	SD
Product 1	**Positive valence**	9	0.22	0.44	0.44	.527	1.22	0.833
Product 2	**Positive valence**	10	0.40	0.52	0.60	0.52	1.10	0.74

A one-way ANOVA was then run to determine if there were significant differences in the positive sentiments used to describe the image schemas employed for the interaction and the levels of quantification, Q (low, medium, and high). A Shapiro-Wilks test (p=0.257) showed that the sentiments expressed were approximately normally distributed for the three groups with effect size (d=0.500). Homogeneity of variance was violated, as assessed by the Levene test of equality of variance (p=0.040), so separate variances and the Welch correction were used. There were statistical differences in the three groups F (2, 24)=6.381 (p=0.060). A Tukey post hoc test conducted revealed that there was a statistically significant difference between the sentiments expressed in the high and low Q groups (p=0.0060) and the high and medium groups (p=0.036). No statistically significant difference was found between the low and medium Q groups (p=0.733).

Similarly for Product 2, a Shapiro-Wilks test (p=0.135) showed that the sentiments expressed were approximately normally distributed for the three groups, with effect size (d=0.416) and Levene test of equality of variance (p=0.862). There were statistically significant differences in the three groups F (2, 27)=3.619 (p= 0.001). A Tukey post hoc test conducted revealed that there was a statistically significant difference between the sentiments expressed in the high and low Q groups (p=0.037). No statistically significant difference were found between the high and medium groups (p=0.168) and the low and medium Q groups (p=0.739). These results indicate that participants with high Q values were more likely to use positive affective words to describe the image schemas employed for the interactions.

Next, the relationship that exists between the number of positive sentiments used for describing the image schemas used for the task and the Q values (the methods used for computing intuitive interaction) of the participants was examined using the Pearson correlation test. The results revealed a positive correlation between Q and the number of positive sentiments in the two products: Product 1: $r(27)=0.561$, $p<0.05$; Product 2: $r(30)=0.446$, $p<0.05$.

These results indicate that the Q values computed for the participants are directly proportional to the positive sentiments used in describing the interaction. That is, as the Q value of the participant increases, the positive sentiment used in describing the image schemas used for the interaction also increases.

In addition, participants' sentiments expressed were compared in the three groups qualitatively. Figures 7.4 and 7.5 show the percentages of participants' sentiments expressed in the use of the image schemas in the three groups for the two products. It was observed that the image schemas associated with more negative sentiments were responsible for the task difficulties experienced by the majority of the participants in the study. These image schemas were identified to appear more in Categories 2 and 3. The image schemas included *path*, *bright-dark*, *attraction*, and *match* for Product 1, while Product 2 included *path, up-down, and bright-dark* (See Appendix H for the positive and negative affective words used for each of the image schemas in the study.)

7.5 DISCUSSION

The empirical study conducted to validate the approach as a means of evaluating the affective aspect of intuitive use revealed positive sentiments linked to the image schemas employed for the interaction. This relationship implies that participants with high Q values were more prone to using positive sentiments to describe their interaction, as opposed to those with low Q values. What these results demonstrate is that *affect* plays a role in intuitive interaction; this is consistent with previous studies (Sinclair et al., 2002).

In addition, the affective evaluation conducted shows that the image schemas used to complete a task are linked to the affective experience of users. This has the potential to lead to significant improvement in design for intuitive use, as the approach directly links experience to the specific image schemas employed in the design.

Furthermore, the qualitative evaluation across the two products used in the study revealed image schemas that were responsible for the task difficulties. It was observed that these image schemas appeared in Categories 2 and 3. For Product 1, the three image schemas comprised *bright-dark*, *path,* and *matching*, while Product 2 comprised *up-down, path, and bright-dark*. The image schemas that were identified to fall into these categories contributed to the low Q values across the two products used in the study.

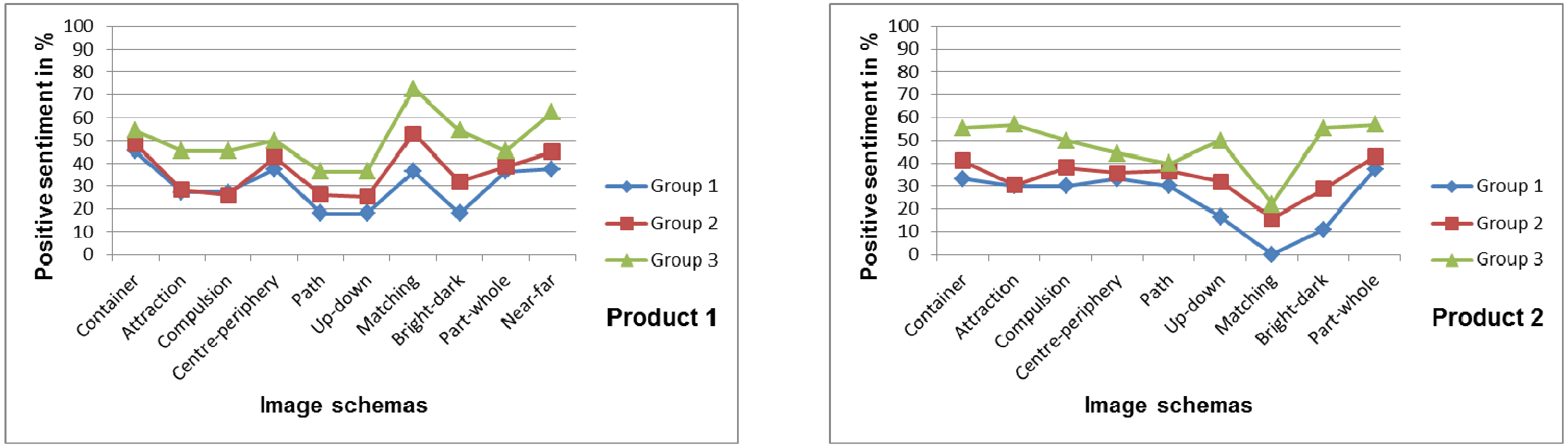


Figure 7.4: Positive Sentiments Used in Describing the Image Schemas

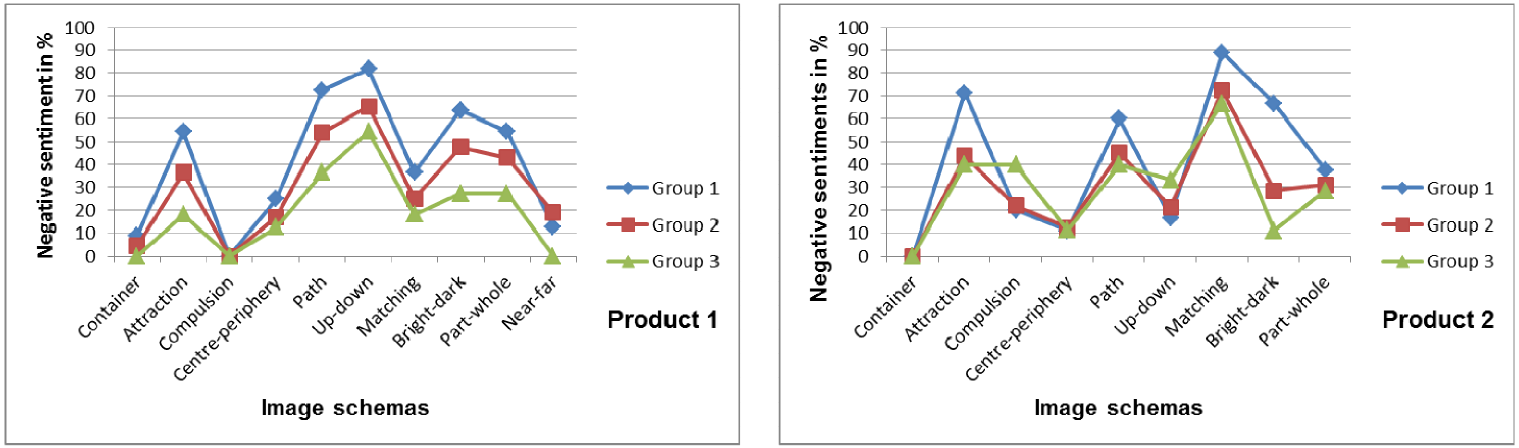


Figure 7.5: Negative Sentiments Used in Describing the Image Schemas

A closer examination of the image schemas responsible for the task difficulties for Product 1 reveals that the *path* image schema generally affected the participants in terms of the function. The step involved in setting the alarm time was very difficult. The designer's ideal of combining buttons to set the alarm time created interaction problems for the majority of the participants. The majority of the participants applied trial and error for the subtask (subtask 2), resulting in less effectiveness and efficiency. The *matching* image schema affected the participants in terms of the presentation of the icon (appearance) used to represent the 'alarm' mode. The use of a 'dot' symbol to represent the alarm mode on the screen was not meaningful to users. The majority of the participants affirmed that they noticed the dot sign, but did not understand what it represented.

For Product 2, the *up-down* image schema affected the participants in terms of the arrangement of the features. The arrangement involves the spatial location of the feature. The participants made more errors and had increased search times as a result of placing the feature to increase the time in the reversed location. Furthermore, the *path* image schema (comprising the feature used to get into the 'alarm' mode) affected participants in terms of the function. The majority of the participants affirmed that they were used to the features 'set' and 'mode' to assess menus in most digital products. This particular product comes with mode and set features. Participants were split between the use of the two buttons to get into 'alarm' mode. Less efficicncy and effectiveness were observed in this subtask (subtask 1) by the majority of the participants. The *bright-dark*, and *matching* image schemas affected participants in terms of the appearance of the feature. The appearance of the feature includes the colour, label, and the icon used for the feature. The poor contrast, in terms of the colour used for the label and the background, created visibility and discriminability problems for the majority of the participants. In addition, the icon used to represent the 'alarm' mode was presented with a poor colour choice that did not attract the attention of the majority of the participants.

This result presented suggest that the approach used in this study can be used to analyse any user interface elements. It has been found that the appearance (size, colour and label) of an interface feature most affects intuitive use (Blackler, 2003a). The effects of the identified image schemas on the interface features can be described based on the approach. If the effects are not those that were intended by the designer, changes can be recommended in order to improve the intuitive use of the product.

Furthermore, the examination of the mental model of the participants on the functionality of the system based on the sequencing of action and system response can be evaluated based on this approach. This can help in detecting interaction difficulties and potential design flaws at the early phase of design.

7.6 SUMMARY

This chapter reported a study conducted using image schemas as a means of assessing the affective aspect of intuitive use. Image schemas were used as the basis for gaining user insights from direct observation and the think aloud protocol of the participants. The approach consists of a novel algorithm that supports the extraction of image schemas from users' transcribed responses. The proposed algorithm provides a formal way of identifying image schemas used in the context of a task based on the verbal responses of the participants. Furthermore, the affective aspect of intuition was utilised as part of the evaluation process, contrary to other studies that have been based on the cognitive aspect.

In conclusion, the empirical studies conducted validated the proposed approach as a means of evaluating the affective aspect of intuitive use based on the sentiments expressed during the study. These findings have the potential to be applied in the domains of product and interaction design.

7.7 General discussion

The concept of intuitive use is a desirable quality criterion in user interface design and evaluation. Considerable progress has been achieved in the last decade by researchers in terms of developing approaches for the design and evaluation of the concept. While these previous approaches are commendable, as they provided a foundation upon which the concept can be abstracted further, the findings have created more opportunities for more research, including the quantitative and affective evaluation of intuitive use. In addition to the existing limitations in the previous methods used in extracting image schemas.

Three studies were conducted in this research in order to address these observed limitations. The outcome of the research includes: a quantitative approach for measuring intuitive interaction was developed based on image schemas; an algorithm for extracting image schemas from user utterances was developed; an ontology used as the knowledge base of the algorithm was specifically developed for the study; finally, an approach for evaluating the affective aspect of intuitive use was developed.

The quantitative approach developed in the study comprises four phases –goal identification, image schema extraction, image schemas analysis and evaluation. In the analysis phase of the quantitative approach, a novel technique was developed for extracting image schemas from multiple methods used in the study. The technique was developed based on a series of observation in the empirical study conducted. Based on the observation, a set of decision rule was developed as a means of resolving conflicts stemming from the coding. This technique was used as a base for deciding which image schema was selected from the combination of the different method. Furthermore, in the evaluation phase, a method for measuring intuitive interaction in quantitative terms was developed based on the degree of match (Quantification, 'Q') of the designer's intent and users' interaction. Thereafter, the validity of the approach was tested as a measure of intuitive use based on the experimental study conducted. The results reveal that participants 'Q' value accounted for intuitive use measured as quicker completion time, fewer errors and less cognitive effort expended. The approach shows that different aspect of the product form can be evaluated based on the approach and could improve interaction design and usability testing.

Some issues were observed in the extraction phase while implementing the quantitative approach, one of which was the complex attributes of image schemas. If image schemas are to be adopted as a means of design and evaluation of intuitive use, there must be a uniform or formal way for its extraction. This aspect was addressed by developing an algorithm for extracting image schemas from user's utterances. The algorithm developed is a knowledge based approach that utilises two ontologies: a lexical ontology and a domain specific ontology purpose built for the needs of the study. The domain specific ontology was developed as a three level classification comprising 5 classes, 20 categories and 40 properties. The unique attribute of the ontology is the technique developed in linking the structural properties of each image schema based on their description of their related concepts in OntoRo. The algorithm extracts image schemas based on a match of the task related word with the image schema ontology. The algorithm was thereafter evaluated based on the comparison of the accuracy of the image schemas identified to be relevant for the completion of the same task by two independent evaluators with knowledge of image schemas. The result reveals an accuracy of almost 70 percent across the 3 products used in the study. This result demonstrates the utility of the developed algorithm and could be deployed as an enhance means of extracting image schema from user's transcribed utterances.

Finally, the last study addresses the affective aspect of intuitive use. From previous literature, the role of affect in intuitive process has generated a lot of debate. Very limited studies have explored this aspect of intuitive use. The affective approach proposed in the study deployed the novel algorithm developed in the previous study to extract the image schemas employed to complete a task, and a sentiment analysis conducted in order to determine the polarity of the affective words linked to the image schemas used in the task. The developed approach links the image schemas used in completing the task to the affective experience of the user based on the positive affective words used to describe the image schemas used for completing the interactions. The approach was validated based on the positive sentiment used in describing the image schemas used for completing the interaction in an empirical study conducted. The result reveals that participant with higher ‘Q’ value were more prone to using positive affective words to describe the image schema used for implementing the interaction. This result actually suggests that affect plays a major role in intuitive process.

CHAPTER 8

CONTRIBUTIONS, CONCLUSIONS AND FUTURE WORK

This research presents the approaches developed for evaluating intuitive interactions with physical objects based on image schemas. Subsequent empirical studies conducted validated the proposed approach as a measure of intuitive use. This chapter summarises the contributions made and conclusions drawn, and discusses possible future directions of the research.

8.1 CONTRIBUTIONS

The main contribution of this research is the development of a quantitative approach for evaluating intuitive interactions based on image schemas. The specific contributions are listed below.

(i) A quantitative approach for measuring intuitive interactions with physical objects was developed to address the first research objective. The contribution addresses most of the current approaches that has been limited to qualitative exploration (Raubal and Worboys, 1999; Maglio and Matlock, 1999; Spool, 2005; Mohs et al., 2006, Hurtienne and Israel, 2007, Hurtienne and Langdon, 2010; Loeffer et al, 2013). The developed approach in this study is divided into four stages, comprising goal identification, image schema extraction, analysis of the extracted image schemas, and the quantitative evaluation of the identified image schemas. In addition, a technique for extracting image schemas from multiple methods was also developed as part of the approach. This technique was derived from the series of observations in the empirical studies that were conducted. Based on the observations, a set of decision rules was formulated as a means of resolving conflicts stemming from the different methods used for extracting the identified image schemas used in the study. This technique was used as a basis for deciding which image schema was selected and used for the analysis. The developed approach quantifies intuitive interaction outputs based on the degree of match represented by the designer's intent and the users' interactions, both expressed through image schemas. The degree of match, known as 'Q' in the study, was afterwards validated as accounting for intuitive use in the series of empirical studies that were conducted. The value of the proposed approach is in the provision of measurable outputs for evaluating intuitive interaction.

(ii) A novel algorithm for extracting image schemas from users' transcribed utterances was developed to address the second research objective. The use of image schemas for design and evaluation of interfaces is dependent on the reliability of the methods used for their extraction. Previous approaches have predominantly relied on the personal expertise of the researcher conducting the study in extracting the identified image schema (Kuhn and Frank, 1991; Hurtienne et al., 2008; Macaranas et al., 2012 Britton et al., 2013). This could introduce subjective bias, thereby reducing its reliability for user interface design and evaluation. As contribution to research in this area, a novel algorithm was developed in the study to address the limitation of previous methods used for their extraction. The entire process of the developed algorithm is divided into four phases- speech to text transcription, semantic expansion of task related words, image schema classification (disambiguation) and image schema extraction. The developed algorithm was evaluated by two independent evaluators with knowledge of image schemas. The results reveals a substantial strength of agreement with an overall k value of 0.67 across the three products used in the study. The results demonstrates the utility of the developed algorithm, and could be used as an enhanced approach for extracting image schema from user transcribed utterances.

(iii) An image schema ontology was developed to address the third research objective. The developed image schema (domain-specific) ontology was used as one of the knowledge bases of the algorithm for extracting image schema from users' utterances. The existing classification is based on two levels, comprising differing classes and categories (Johnson, 1987; Lakoff, 1999; Dodge and Lakoff, 2005; Langdon and Clarkson 2007; Hurtienne, 2011). The image schema ontology developed in the study was built on three level classification system comprising five classes, twenty categories and forty properties. The unique attribute of the ontology is the technique developed in linking the properties of each image schema used in the study based on their description of their related concept in OntoRo. The ontology was developed to cover substantial numbers of the image schemas identified in previous studies to be relevant for intuitive interactions. More than half of the twenty image schemas used for developing the ontology were from the spatial and attribute classes that had been identified as relevant for intuitive use.

(iv) An approach for assessing the *affective* aspect of intuitive interactions with products was developed to address the fourth research objective. This contribution addresses previous studies that have predominantly focused on the cognitive aspect of the evaluation of intuitive use of interfaces (Hurtienne and Blessing, 2007; Fischer et al., 2009; Blackler et al., 2010; Antle et al., 2011; Britton et al., 2013). The approach developed in this study incorporates the novel algorithm for extracting image schemas, a specific domain ontology developed for the study, and a sentiment analysis that was conducted as part of the evaluation process. The proposed approach is evaluated based on the sentiments used in describing the image schemas employed for the interaction. The results shows that the approach links the image schemas used for the completion of the task to the affective experiences of the users. These results demonstrate that affect plays a role in intuitive interaction.

8.2 CONCLUSIONS

This study has explored the concept of intuitive use based on image schemas. In the course of conducting the study, three significant research gaps were identified from which four research objectives were formulated in chapter 1. These research objectives guided the design and execution of the work presented in chapters 4 to 7. The following conclusions were drawn from the research conducted in the current study.

- The study has found that image schemas can be used as an approach for evaluating the concept of intuitive use based on a series of empirical study conducted to illustrate how the proposed quantitative approach can be concretely applied to measure intuitive interaction in a set of products (Chapter 5, pp. 73-91).
- The quantitative approach developed in the study (Chapter 5, pp. 73-91) can be used to evaluate different aspects of the product semantics, which has been found to facilitate intuitive use. For example, the appearance of the feature- comprising size, colour and icon captured as the product semantics can easily be represented and evaluated with image schemas based on this approach.
- The evaluation of the proposed methods used for extracting image schema (Chapters 4 and 5, pp. 62-63; 103-104) has revealed that the direct observation and the think aloud protocol methods were sufficient to be employed in identifying image schemas in future studies due to their high identification and extraction rate when compared to questionnaires and interviews.

- In the extraction phase of the developed quantitative approach (Chapter 5, pp.73-86), the study has found that some image schemas can pose problems in terms of their interpretation in the context of the interaction as a result of their multiple attributes. This issue was observe in the study to be the bases upon which the independent evaluators provided justification for the choice of the image schemas identified to be relevant in the context of interaction.
- In the assessment phase of the developed quantitative approach (Chapter 5, pp.88-91), the study has shown that by using a method for quantification of image schemas matching, interactions difficulties can be coded in terms of image schemas; this has the potential to lead to improvement in interaction design and may provide a new structured approach to usability testing.
- The physiological measurement based on the blink rate proposed to be used in the study as one of the means for measuring the cognitive load of the participants (Chapter 5, pp. 71, 104) produced a disappointing results. This was due to the obstructive nature of the wearable eye tracking glasses used in the study.
- The use of a knowledge-based system for extracting image schemas in the study (Chapter 6, pp. 129-134) shows many positive aspects, and could improve the accuracy of the image schemas used for the assessment phase based on the evaluation of the proposed algorithm developed for extracting image schema.
- The study has also revealed the utility of using the proposed algorithm for extracting image schemas (Chapter 6, pp.119-129) and could be used as enhanced approach for extracting image schemas from user's transcribed utterances.

- The empirical study conducted to evaluate the developed affective approach (Chapter 7, pp. 143-157) shows that the image schema concept can be used to map the structure of the task to the affective experience of the users. This approach directly linked experience to the specific image schemas employed in the design.

8.3 LIMITATIONS

The current study considers intuition to be a process that comprises both cognitive and affective aspects. While conducting the empirical studies to investigate the two core aspects of intuitive use, a couple of issues were observed in the implementation of the approach:

(1) There was a limitation in the means used in gaining users' insights into the affective aspect of intuitive use. Although the study proposed the use of subjective rating (which involved an analysis of the users' verbal comments) and a physiological measurement (based on the users' pupil radii) for assessing the affective aspect of intuitive use, the physiological data processed from the SMI eye tracking glasses (SensoMotoric Instruments) in the first study produced disappointing results during the evaluation. This was attributed to the noises produced due to the obstructive nature of the wearable eye tracking glasses used in the study. The obstructive nature of the eye tracking hardware contributed substantially to the distraction experienced by the majority of the participants in the study. Consequently, only the analyses of the verbal comments were used in evaluating the affective aspect of intuitive use in this study. Considering the sensitive nature of physiological data extracted from the eye tracking hardware, which are susceptible to contamination, it will be instructive in future studies to consider using a desk mounted tracking hardware to reduce the effect of the noises produced from the wearable eye tracking glasses.

(2) Although the algorithm developed does have some limitation as observed during the study. The issues observed were generally related to the number of image schemas used for developing the knowledge base of the algorithm. The ontology that was deployed as the knowledge base of the algorithm was developed for twenty image schemas. This number of image schemas used in the study covers 75 percent of the image schemas that have been found to be useful for tangible interaction in previous studies (Hurtienne et al, 2009, Hurtienne, 2011 and Maracanas, 2012). There were however a few cases where the image schema was identified by one of the independent evaluators, but was not captured by the algorithm. Consequently, the image schema was not identified by the algorithm. This aspect of the limitation could be addressed by increasing the number of image schemas used in developing the ontology, and testing resulting ontology across a wide range of products in future studies.

8.4 FUTURE WORK

Although the study conducted has demonstrated that the approach developed is valuable for evaluating intuitive interactions with products, some aspects could potentially be improved upon. This aspect will form the future direction of this research.

First, future studies should consider implementing the approach into a typical industrial design process. This would involve an analysis of the technology readiness level (TRL) of the developed approach. The TRL provides a checklist for monitoring technology development. This study has observed and reported on the basic principles underlying the approach it took. In addition, the domain of application was formulated and experimentally validated. The next phase would involve developing a prototype based on the approach, and conducting an evaluation study based on the prototype developed against the conventional products available in the market.

A second area that is worth investigating further is the adaptability of the developed algorithm for extracting image schemas across a wide range of products. This would involve testing the accuracy of the image schemas extracted by the algorithm across a wide range of products.

A third aspect that could form the future direction of this research is the application of the approaches developed in the study to other domains. For example, future work could consider the application of the developed algorithm as a tool for identifying image schemas in cognitive linguistics and interior design.

APPENDIX A:

COMBINATION OF THE METHODS USED FOR EXTRACTING IMAGE SCHEMAS

The combination used in the study is in this order:

- Direct observation,
- Think aloud protocol,
- Questionnaire
- Interview.

Image schemas that are correctly used in accordance with the designer's intent is coded as 1; incorrectly used, coded as 2 while trial and error is coded as 3.

Table A.1: Image Schema Appearing in Category 1 by Questionnaire and Interview

Questionnaire 1 / Interview 1		Think aloud		
		1	2	3
Direct observation	1	1111	1211	1311
	2	2111	2211	2311
	3	3111	3211	3311

Table A.2: Image Schema Appearing in Category 2 by Questionnaire and Category 1 by Interview

Questionnaire 2 / Interview 1		Think aloud		
		1	2	3
Direct observation	1	1121	1221	1321
	2	2121	2221	2321
	3	3121	3221	3321

Table A.3: Image Schema Appearing in Category 3 by Questionnaire and Category 1 by Interview

Questionnaire 3 / Interview 1		Think aloud		
		1	2	3
Direct observation	1	1131	1231	1331
	2	2131	2231	2331
	3	3131	3231	3331

Table A.4: Image Schema Appearing in Category 1 by Questionnaire and Category 2 by Interview

Questionnaire 1 / Interview 2		Think aloud		
		1	2	3
Direct observation	1	1112	1212	1312
	2	2112	2212	2312
	3	3112	3212	3312

Table A.5: Image Schema Appearing in Category 2 by Questionnaire and Interview

Questionnaire 2 / Interview 2		Think aloud		
		1	2	3
Direct observation	1	1122	1222	1322
	2	2122	2222	2322
	3	3122	3222	3322

Table A.6: Image Schema Appearing in Category 3 by Questionnaire and Category 2 by Interview

Questionnaire 3 / Interview 2		Think aloud		
		1	2	3
Direct observation	1	1132	1232	1332
	2	2132	2232	2332
	3	3132	3232	3332

Table A.7: Image Schema Appearing in Category 1 by Questionnaire and Category 3 by Interview

Questionnaire 1 / Interview 3		Think aloud		
		1	**2**	**3**
Direct observation	**1**	1113	1213	1313
	2	2113	2213	2313
	3	3113	3213	3313

Table A.8: Image Schema Appearing in Category 2 by Questionnaire and Category 3 by Interview

Questionnaire 2 / Interview 3		Think aloud		
		1	**2**	**3**
Direct observation	**1**	1123	1223	1323
	2	2123	2223	2323
	3	3123	3223	3323

Table A.9: Image Schema Appearing in category 3 by Questionnaire and Interview

Questionnaire 3 / Interview 3		Think aloud		
		1	**2**	**3**
Direct observation	**1**	1133	1233	1333
	2	2133	2233	2333
	3	3133	3233	3333

Appendix B

Screening questionnaire

You are being invited to take part in a research project organised as part of my PhD degree in the Institute of Mechanical and Manufacturing Engineering, Cardiff University.

The study aims at exploring intuitive interaction with products. This involves observing user's interaction with everyday objects. Your participation in the study will help to provide better guidelines for effective product design.

To this end, the screening questionnaire attached is intended to provide basic information that will be needed to organise the experiment. Please fill it carefully and return it as soon as you can. We will contact you to organise a day and time for your participation.

Thank you.

Screening Questionnaire

Participant's ID:

Date:

Age:

Gender:

E- Mail address:

Tel. No.:

Educational qualification:

How often do you use a digital alarm clock including built-in?

Everyday Few times per week Once or twice a week

Less often than once a week In the past but not n Never

Could you please tick other digital products you have used?

Clock radio Calculator Washing machine

Microwave Remote control Mobile phone

How often do you use a clock radio?

All the time Sometimes Rarely Never

How many of the clock radio features you have used?

All the features As many features as you can figure out

Just enough to get started None of the features

How often do you use a calculator?

All the time Sometimes Rarely Never

How many of the calculator features you have used?

All the features As many features as you can figure out

Just enough to get started None of the features

How often do you use a washing machine?

All the time Sometimes Rarely Never

How many of the washing machine features you have used?

All the features As many features as you can figure out

Just enough to get started None of the features

How often do you use a micro wave?

All the time Sometimes Rarely Never

How many of the micro wave features you have used?

All the features As many features as you can figure out

Just enough to get started None of the features

How often do you use a remote control?

All the time Sometimes Rarely Never

How many of the remote control features you have used?

All the features As many features as you can figure out

Just enough to get started None of the features

How often do you use a mobile phone?

All the time Sometimes Rarely Never

How many of the mobile phone features you have used?

All the features As many features as you can figure out

Just enough to get started None of the features

Appendix C: Questionnaire used in study 1

Section one: Demographic information

Participants' number:

Name:

Gender:

E-mail**:**

Section two: User experience

Do you currently use an alarm clock?

If yes, could you please describe the type of alarm clock you have used in the past?

Could you tell us the individual steps as well as the specific features used for the completion of the current task?

Do you think your previous experience of other digital products helped in the completion of the task?

Section three: Rating scale

How much cognitive effort was required for the completion of the task?

Very high	High	Average	Low	Very low
1	2	3	4	5

How satisfied are you generally with the use of the alarm clock

Highly satisfied	Satisfied	Average	Dissatisfied	Highly Dissatisfied
1	2	3	4	5

Could you tell us the reasons that influenced your ratings?

Appendix D: Transcript of the Interview Used in study 1

(1) Did you feel anxious when completing the task? If yes, could you please tell us why?

(2) Could you please rate your confidence level in terms of completing the task on a scale of 1-5, with 1 highly confident while 5 no confident?

(3) Did you notice any change in the display while completing the task?

(4) Did the product use meet your expectation? If no, could you please tell us why?

(5) Are there any parts of the task you considered to be the most difficult? If yes, please describe the nature of this difficulty?

Appendix E: Independent Evaluation Study Data

Thank you for volunteering to assist with my study.

A User study was conducted using image schemas as a means of exploring intuitive interaction. Image schemas were extracted in the study from the designer's intent through the task steps and product feature description; and the users' interactions using think aloud, direct observation, questionnaire and interview.

The purpose of this study is to evaluate the accuracy of the image schemas extracted from the user study. As an independent evaluator, you will be provided with two sets of data in the user study: transcript of the think aloud of the participants and the task steps and product description from the designer's documentation. In addition, you will be provided with the description of the list of image schemas used for the study.

You will be asked to extract the relevant image schemas that best describe the task from the sets of data.

All information will be treated with confidentiality.

Thank you.

Appendix E: 1

Image schemas description used in the study

S/n	Category	Properties	Linguistic usage	Interface design	Inference
1	Container	A CONTAINER consists of a Boundary that separates an Interior (space enclosed by the Boundary) from the Exterior (the surrounding area - space not enclosed by the Boundary) and, often, a Portal (an opening in the Boundary that allows motion between the Interior and the Exterior) [Dodge & Lakoff, 2005:62]	Have they entered into an agreement yet? [Lakoff et al., 1991:33] I can't get this idea *out of my mind*. [Lakoff et al., 1991:94] The ship is *coming into* view. [Lakoff & Johnson, 1980:30] How did I get myself into this situation? [Lakoff et al., 1991:75]	central screen play a primary role by information indicating between machine and user	Screen is a Container, which has a boundary, interior and exterior. Information is inside the screen.

			He's out of the race now. [Lakoff & Johnson, 1980:31] He fell into a depression. [Lakoff & Johnson, 1980:32]		
2	Content	The CONTENT image schema describes everything that is inside a CONTAINER	He has a pain in his shoulder. [Lakoff & Johnson, 1980:50] The sight filled her with fear. [Stefanowitsch:24] He has a great capacity for learning. [Lakoff et al., 1991:12]	central screen play a primary role by information indicating between machine and user	Content of the container is information for the user
3	Full empty	The image schema FULL-EMPTY is used to describe the fill level of a CONTAINER.			

4	In- Out	The IN-OUT schema denotes the location of an entity within or outside of a CONTAINER/bounded area or the movement into or out of a CONTAINER.	let the cat out of the bag [Clausner & Croft, 1997:265]	Arrows point Up and Down. It indicates dynamic action with direction	UP means OUT DOWN means IN
5	Surface	The SURFACE image schema denotes a two-dimensional, often flat, area. Often it denotes the outside of a material body.	We covered a lot of ground. [Lakoff & Johnson, 1980:90-91]. We have already covered those points. [Lakoff & Johnson, 1980:91]		
6	Object	Objects are usually seen as bounded entities toward which thought, feeling, or action is directed.	You rarely find that kind of opportunity. [Lakoff et al., 1991:68]. I want control over my own existence. [Lakoff et al., 1991:71].	The button is an OBJECT sticking out of the background	I. The objectness of the button affords manipulating it ii. Convey structural and navigational understanding to user

7	Substance	Unbounded homogenous regions of material		A solid progress indicator might be seen as a substance	I Time is a moving substance
8	Attraction	ATTRACTION is a force image schema in which a (passive) object exerts a force on another object, either physically or metaphorically, to pull it toward itself (or in the case of REPULSION to repel it), mostly acting from a distance.	That coat pulled me into the store. [Lakoff et al., 1991:23] I was drawn to him. [Lakoff et al., 1991:156]	Indicating lamp	The Blinking sign ATTRACTS the user that an action need to be performed.
9	Balance	BALANCE is a force image schema that provides an understanding of physical or metaphorical counteracting forces: forces and/or weights counteract/balance off one another. Metaphorically, there is equilibrium, not “too much” and not “not enough”.	He weighed the ideas in his mind. [Jäkel:167] You have to weigh the pros and cons. [Lakoff et al., 1991:62]	Using automatic teller keypad to enter pin numbers or some characters	Keys are sorted according to a definite balance. - The sorted keys will optimise user's control process.
10	Blockage	BLOCKAGE is a force image schema in which a force / movement is physically or metaphorically stopped or redirected by an obstacle.	Harry got over his divorce. [Lakoff & Johnson, 1999:189] The way of the lazy is overgrown with	Password is Required	Without password machine can't take any reaction

			thorns, but the path of the upright is a level highway. [Jäkel, 2003:270]		
11	Compulsion	COMPULSION is a force image schema that involves an external force physically or metaphorically causing some passive entity to move.	She pushed me into doing it. [Lakoff, 1990:58]	I will need to press this button to get into this mode.	Press activate the movement along a path
12	Counterforc e	COUNTERFORCE is a force image schema that involves the active meeting of physically or metaphorically opposing forces that are equally strong. Both forces collide, there is no further movement.	His cheerfulness can counteract this Our confidence in you clashed [Pena, 1999]	At the right moment when bank card touched the ATM,user will feel the Counter force.	The counterforce is a sign to user:stop pushing
13	Diversion	DIVERSION is a force image schema that involves forces that physically or metaphorically meet and produce a change in direction or force vectors (at least one).	He turned into a monster. [Lakoff et al., 1991:18]		
14	Enablement	ENABLEMENT is a force image schema that involves having (a) the physical or metaphorical power to perform some act, or a potential force (vector) and the absence of BLOCKAGE, RESISTANCE, COUNTERFORCE, COMPULSION; (b) a "felt sense of	It is smooth sailing from here on in. [Lakoff, 1990:58] She walked him through it. [Lakoff,	After inputting the bank card, ATM will work at once	Absence of blockage

		power to perform some action”	1990:59]		
15	Momentum	MOMENTUM is a force image schema that involves the tendency of an object to maintain the actual state of motion (or rest) if there is no influence of another agent.			
16	Resistance	RESISTANCE is a force image schema that involves a force that tends to oppose or retard the motion of another entity.	We are going upstream. [Lakoff, 1990:58]		
17	Restraint remover	RESTRAINT REMOVAL is a force image schema that involves the physical or metaphorical removal of a barrier to the action of a force, or absence of a barrier that was potentially present.	His good and her bad feelings yielded to love. Real Journalists keep their feelings from getting in the way. [Pena, 1999]	Input Password	Inputting correct password activate the process to go ahead
18	Self motion	SELF MOTION occurs when a resting entity starts moving without any forces acting on it.	He can exert his influence on her. [Lakoff et al., 1991:131] That was a terrible blow. [Stefanowitsch:32]		

			He drove her crazy. [Lakoff & Johnson, 1999:184]		
19	Centre-periphery	The CENTER-PERIPHERY image schema consists of an ENTITY, a CENTER, and a PERIPHERY.	What is central here? [Lakoff et al., 1991:13] She put the idea to the back of her mind. [Jäkel:158-159]	Scroll arrows are at the PERIHERY of the scroll bar. Ii Screen is CENTER, other devices are PERIPHERY.	I. Scroll arrows point to the destination of the PATH the scroll box should take ii User will pay more attention to central screen.
20	Contact	the physical coming together of two or more things (wordnet.princeton.edu)	His mother's death hit him hard. [Lakoff & Johnson, 1980:50] We talk and talk, but I can't seem to reach him. [Lakoff et al., 1991:156]	The push button CONTACTS the inner right border, the list of items (opened) CONTACTS the	I. CONTACT indicates that all these items belong together.

			He's out of touch with everyone.	outer lower border of the text box ii User's finger contacts screen surface.	Ii Select an option to enable next step control.
21	Front back	FRONT: the side that is forward or prominent; the side that is seen or that goes first BACK: the side that goes last or is not normally seen; the part of something that is furthest from the normal viewer (wordnet.princeton.edu)	In the weeks ahead of us … [Lakoff & Johnson, 1980:41] In the following weeks …[Lakoff & Johnson, 1980:41] We are moving ahead. [Lakoff, 1990:60]	knobs which can be push or pull. Ii a lever which can move forward and back. Iii a switch which can move forward and back	I. when you press the Knob the the data will enter, when you pull the knob the data will delete. Ii forward to increase, backward to decrease. Iii forward to start the engines, backward to

					power down the engines
22	Left right	LEFT: being or located on or directed toward the side of the body to the west when facing north RIGHT: being or located on or directed toward the side of the body to the east when facing north (wordnet.princeton.edu)		i. Arrow buttons point LEFT and RIGHT. Ii Arrow buttons point LEFT and RIGHT in Calendar. Card reader is in the Right side of screen	I. MORE IS RIGHT, LESS IS LEFT. Ii The past is LEFT, the future is RIGHT
23	Location				
24	Near far	The NEAR-FAR image schema is a topological abstraction related to the spatial proximity and distance of entities or sets of entities. The image schema NEAR-FAR can be both, static and dynamic. In the dynamic state, it is concerned with approach (towards) and departure (away from).	These colours aren't quite the same, but they're close. [Lakoff & Johnson, 1999:51] He is very near and dear to her. [Lakoff et al., 1991:155] Three O'clock is approaching. [Lakoff	the corresponding label is NEAR the radio button in a radio player. Slot (to deposit a coin or print a receipt) and card reader r	i. Closeness links label and button together. There are images and words near the slot explaining its function. User can recognise nearest images and words to know how it works.

			et al., 1991:76]		
25	Path	A PATH consists ofa source or starting point, a goal or end-point, and a sequence of contiguous locations connecting the source with the goal. [Johnson, 1987:113] Synonyms FROM-TO SOURCE-PATH-GOAL	He went from fat to thin through an intensive exercise program. [Lakoff et al., 1991:21] It took him hours to reach a state of perfect concentration. [Lakoff et al., 1991:8] As we travel down life's path. . . [Lakoff et al., 1991:36] We reason from premise to conclusion. [Lakoff et al., 1991:90] When will he come to the point? [Lakoff et	the wizard establishes a PATH with several steps. Ii The scroll box travels along a PATH set by the scroll shaft	I. From a starting point the user is taken to a destination (his goal) by the wizard. Ii Scrollbox position shows distance of visible portion from top (left) edge of the document

			al., 1991:91] We've reached the end. [Lakoff, 1990:60]		
26	Scale	A SCALE image schema builds on the PATH image schema with added cumulativity, normativity, and fixed directionality. It is used to refer to numbers of objects, amounts of substances, degrees of force, or intensities of sensations.		clock: information displayed on a scale. Ii parameters are displayed on a scale	to give exact information about time. Ii to give exact information about engine parameters
27	Straight	Straight is connected to rectangles, rectilinearity and to being right / upright.	He's on the straight and narrow path. [Lakoff et al., 1991:185]		
28	Up down		That boosted my spirits. [12:14-21; Lakoff & Johnson, 1980:15]	a lever which can move up and down.	ii. lever down for landing gear down, lever up for gear up.

			a high-pitched voice He dropped his voice.	ii. Arrow keys and Page UP-DOWN keys can be used to navigate the list	ii. Arrow keys and Page UP-DOWN keys can be used to navigate the list
29	Rotation				
30	Cycle	Most fundamentally, a CYCLE is a temporal circle. The cycle begins with some initial state, proceeds through a sequence of connected events, and ends where it began, to start anew the recurring cyclic pattern. (Johnson, 1987, p. 119) Synonyms: RHYTHM - NO RHYTHM (Krzeszowski, 1997)	Process Flowchart.	The process is a Cycle. It works again by another user s control	It start all over as soon a the process ends
31	Iteration		Mappings [Lakoff & Nunez, 2000:62] The repeated	Password error circle. Correct password is required	Because of the wrong password, user need to input the password again

			addition (A times) of a collection of size B to yield a collection of size C. --> Multiplication (A*B=C) The repeated subtraction of collections of size B from an initial collection of size C until the initial collection is exhausted. A is the number of times the subtraction occurs. --> Division (C/B=A)		
32	Collection	several things grouped together or considered as a whole (wordnet.princeton.edu)	Add sugar to my coffee.	Using automatic teller keypad to enter pin numbers or some characters	From user's aspect of view COLLECTION is keys. It is always beneficial to input if all useful keys are **collected** together
33	Count - mass	COUNT denotes a set of discrete items with a network of divisional spacing, MASS is a coherent whole without internal differentiation		For navigation or other purpose arrow keys are important components for	Key group (MASS) is composed with keys (MASS)

		[Talmy, 1983]		ATMs	
34	Link	The LINK image-schema consists of two or more entities which are connected with each other by means of a linking device of some kind.	There's strong bond between them. [Kövecses, 2002:74] breaking social ties [Santibanez, 2001:188]	For navigation or other purpose arrow keys are important components for ATMs	A definite function shown on screen is linked with the nearest key. If user clicks the key, relative function will be executed
35	Matching			Slot (to deposit a coin or print a receipt) and card reader	Length of slot is Matched with bank card or receipt. If the length of the bank card is too long, it may not be inserted.
36	merging				
37	Part-whole	PART-WHOLE is an image schema that consists of a whole, parts, and a configuration.	Something is missing in that argument. [Lakoff et al., 1991:138]. We are one. [Lakoff et al., 1991:154]	Using automatic teller keypad to enter pin numbers or some characters	The Keyboard is seen as PART of the WHOLE machine.

38	Splitting		The story is not primarily about salvation, but about severe judgement, and it ends in tragedy, in hopes dashed most cruelly to smithereens. [Santibanez, 2002:193].		
39	Big-small		That's a big discovery. [Lakoff et al., 1991:13] He's short of money. [Lakoff et al., 1991:14] He's a big man in the garment industry. [Lakoff & Johnson, 1980:50].	That large button appears to be what is use to control the process	Big is associated with important or significant things
40	Bright-dark	BRIGHT: emitting or reflecting light readily or in large amounts DARK: devoid of or deficient in light or brightness; shadowed or black (having dark hue when used with	His sunny smile lit up the room. [Raymond:112]		

		colours) [wordnet.princeton.edu]	He is in a dark mood [Stefanowitsch:32] This is brilliant work. [Tolaas, 1991:209] A bright boy learns quickly. [Tolaas, 1991:209]		
41	Fast slow				
42	Hard-soft				
43	Heavy light		He's a heavy smoker. [Lakoff et al., 1991:14] burden of sadness [Stefanowitsch, 2006:34]		
44	Strong weak				
45	Warm cold		anger melt away [Stefanowitsch:22]		

			fear make X feel warm [Stefanowitsch:27]		

Appendix F: 'Q' Values Computed for each Image Schemas Used in Study 1

Table F.1: ‘Q’ Scores for the Image Schemas Used for Product 1

Participants	Up- down, %	Cetre-periphery, %	Attraction, %	Path, %	Container, %	Matching, %	Bright –dark, %	Compulsion, %
1	28.50	100.00	33.20	36.80	100.00	16.20	28.80	100.00
2	45.65	100.00	52.63	42.30	100.00	41.65	46.50	100.00
3	36.10	100.00	38.80	39.85	100.00	32.40	16.80	100.00
4	25.18	100.00	35.63	30.55	100.00	36.58	19.40	100.00
5	23.24	100.00	28.65	28.50	100.00	31.65	22.65	100.00
6	48.25	100.00	46.80	43.50	100.00	43.50	43.60	100.00
7	40.25	100.00	48.65	42.56	100.00	48.65	50.25	100.00
8	14.23	100.00	23.65	33.80	100.00	20.80	22.65	100.00
9	30.44	100.00	32.85	26.58	100.00	33.45	28.45	100.00
10	50.80	100.00	48.65	50.65	100.00	58.35	41.80	100.00
11	36.87	100.00	24.31	26.30	100.00	26.25	29.60	100.00
12	40.22	100.00	46.50	44.65	100.00	38.45	48.60	100.00
13	47.35	100.00	52.80	48.30	100.00	55.35	44.45	100.00
14	14.21	100.00	22.25	36.80	100.00	28.80	37.75	100.00
15	51.25	100.00	40.60	41.66	100.00	42.90	60.30	100.00
16	46.45	100.00	53.25	46.50	100.00	58.65	56.80	100.00
17	34.33	100.00	38.00	28.65	100.00	19.90	36.50	100.00
18	46.00	100.00	52.50	45.45	100.00	58.00	55.00	100.00
19	50.83	100.00	46.50	50.20	100.00	51.50	46.80	100.00
20	21.85	100.00	32.50	36.50	100.00	29.90	26.80	100.00
21	30.25	100.00	36.55	34.38	100.00	36.55	31.52	100.00
22	52.25	100.00	46.25	42.20	100.00	43.50	56.85	100.00
23	19.98	100.00	21.88	36.50	100.00	36.50	24.60	100.00
24	27.78	100.00	28.20	30.88	100.00	25.25	36.50	100.00
25	46.80	100.00	42.44	45.85	100.00	48.80	45.85	100.00
26	46.22	100.00	48.50	53.60	100.00	41.25	50.25	100.00
27	52.45	100.00	52.80	58.25	100.00	46.38	43.85	100.00

28	43.40	100.00	48.80	46.20	100.00	49.50	58.20	100.00
29	38.65	100.00	30.65	21.65	100.00	25.45	28.80	100.00
30	30.00	100.00	23.45	33.80	100.00	36.75	33.65	100.00

Table F.2: 'Q' Scores for the Image Schemas Used for Product 2

Participants	*Up- down, %*	*Centre-periphery, %*	*Attraction, %*	*Path, %*	*Container, %*	*Matching, %*	*Bright –dark, %*	*Compulsion, %*	*Content, %*	*Restraint remover, %*
1	62.35	100.00	58.30	10.25	100.00	12.45	19.50	100.00	100.00	4.00
2	75.80	100.00	66.65	25.65	100.00	18.90	13.45	100.00	100.00	6.50
3	64.40	100.00	60.67	20.85	100.00	22.45	13.15	100.00	100.00	8.50
4	53.25	100.00	45.45	13.35	100.00	6.65	16.14	100.00	100.00	3.20
5	66.70	100.00	58.95	30.36	100.00	12.54	7.20	100.00	100.00	-
6	60.50	100.00	72.70	40.26	100.00	15.85	13.98	100.00	100.00	4.80
7	48.97	100.00	54.45	15.50	100.00	10.00	7.65	100.00	100.00	2.00
8	55.67	100.00	55.50	6.20	100.00	8.5	15.30	100.00	100.00	-
9	72.80	100.00	55.55	38.20	100.00	32.45	7.93	100.00	100.00	10.60
10	61.95	100.00	65.78	26.75	100.00	14.35	7.45	100.00	100.00	3.60
11	60.30	100.00	62.54	10.90	100.00	6.50	11.90	100.00	100.00	-
12	70.85	100.00	75.20	33.74	100.00	14.75	11.05	100.00	100.00	10.25
13	45.45	100.00	50.80	12.45	100.00	5.50	12.24	100.00	100.00	2.20
14	77.80	100.00	61.25	9.95	100.00	22.65	7.25	100.00	100.00	-
15	50.25	100.00	48.70	10.60	100.00	10.00	12.34	100.00	100.00	-
16	58.20	100.00	63.24	22.25	100.00	20.80	14.38	100.00	100.00	11.35
17	58.35	100.00	50.20	11.85	100.00	11.45	22.05	100.00	100.00	3.50
18	69.50	100.00	57.26	20.45	100.00	16.30	3.25	100.00	100.00	10.55
19	55.55	100.00	42.90	10.25	100.00	7.72	6.58	100.00	100.00	4.25
20	60.30	100.00	53.85	12.30	100.00	8.55	12.59	100.00	100.00	-

Table F.3: 'Q' Scores for the Image Schemas Used for Product 3

Participants	Up- down, %	Centre-periphery, %	Attraction, %	Path, %	Container, %	Matching, %	Cycle, %	Bright –dark, %	Compulsion, %	Content	Front-back, %	Rotation, %
1	40.25	100.00	9.60	30.65	100.00	50.25	70.86	-	100.00	50.20	100.00	100.00
2	65.26	100.00	17.85	50.75	100.00	70.20	90.50	10.90	100.00	78.65	100.00	100.00
3	75.25	100.00	12.80	43.65	100.00	65.75	87.85	16.75	100.00	70.90	100.00	100.00
4	42.85	100.00	4.50	30.65	100.00	52.35	70.45	10.00	100.00	55.90	100.00	100.00
5	80.60	100.00	22.45	60.20	100.00	82.35	83.85	17.85	100.00	71.85	100.00	100.00
6	50.40	100.00	6.75	23.75	100.00	45.75	60.30	12.80	100.00	44.35	100.00	100.00
7	66.63	100.00	16.75	52.78	100.00	68.95	90.50	13.25	100.00	65.44	100.00	100.00
8	40.25	100.00	14.50	20.62	100.00	50.20	65.80	8.95	100.00	52.85	100.00	100.00
9	72.75	100.00	20.40	43.30	100.00	70.70	87.85	18.95	100.00	71.85	100.00	100.00
10	45.65	100.00	12.25	18.90	100.00	55.45	70.45	6.75	100.00	50.52	100.00	100.00
11	66.75	100.00	12.70	65.67	100.00	78.54	90.55	22.35	100.00	80.75	100.00	100.00
12	40.68	100.00	5.50	21.35	100.00	44.25	60.22	9.90	100.00	52.80	100.00	100.00
13	70.20	100.00	18.25	42.50	100.00	75.50	85.45	24.65	100.00	65.65	100.00	100.00
14	45.90	100.00	4.50	19.50	100.00	43.85	80.45	4.50	100.00	55.75	100.00	100.00
15	48.75	100.00	12.65	20.60	100.00	40.25	72.54	8.90	100.00	50.25	100.00	100.00
16	60.25	100.00	16.82	32.35	100.00	70.80	88.85	14.76	100.00	77.85	100.00	100.00
17	45.82	100.00	6.75	17.80	100.00	60.05	80.65	4.65	100.00	52.25	100.00	100.00

18	67.25	100.00	25.65	45.55	100.00	55.80	82.75	18.90	100.00	82.25	100.00	100.00
19	45.55	100.00	7.75	25.50	100.00	55.45	61.95	-	100.00	40.30	100.00	100.00
20	65.75	100.00	15.40	45.70	100.00	60.50	80.90	15.65	100.00	65.45	100.00	100.00
21	42.35	100.00	4.65	28.95	100.00	45.25	75.60	7.80	100.00	42.35	100.00	100.00
22	60.05	100.00	18.75	40.10	100.00	71.25	91.25	18.90	100.00	74.50	100.00	100.00

Appendix G

Methods Used in Developing the Image Schema Ontology Employed in the Study

Table G.1: Image Schema Ontology Development

Class	Categories	Definition	Structural element	Concept	Relevant concept
Containment	Container	A ***CONTAINER*** consists of a *Boundary* that separates an *Interior* (space enclosed by the Boundary) from the *Exterior* (the surrounding area - space not enclosed by the Boundary) and, often, a *Portal* (an opening in the Boundary that allows motion between the Interior and the Exterior) (Dodge and Lakoff, 2005)	Interior	5: Intrinsicality 58: Component 78: Inclusion 224: Interiority 344: Land 553: Painting	224: Interiority
			Exterior	6: Extrinsicality 59: Extrenousness 223: Exteriority 445: Appearance 875: Ostentation:	223: Exteriority
			Movement into (Ingress)	297: Ingress 305: Passage	297: Ingress

			Movement out of (Egress)	296: Departure 298: Egress 305: Passage 46: Disunion 69: End 234: Edge	298: Egress
	Content	The CONTENT image schema describes everything that is inside a CONTAINER (ISCAT, 2012)	Interior (inside)	5: Intrinsicality 58: Component 78: Inclusion 224: Interiority 344: Land 553: Painting	224: Interiority
	In out	The IN-OUT schema denotes the location of an entity within or outside of a CONTAINER/bounded area or the movement into or out of a CONTAINER (Johnson,	Inside	193: Content 224: Interiority 747: Restraint	224: Interiority

		1987).		59: Extrenousness 223: Exteriority 230: Sorrounding 445: Appearance 541: Falsehood	
			Outside	6: Extrinsicality 59: Extrenousness 223: Exteriority 445: Appearance 875: Ostentation:	223: Exteriority
			Movement into (Ingress)	297: Ingress 305: Passage	297: Ingress
			Movement out of (Egress)	296: Departure 298: Egress 305: Passage	298: Egress
Space	Centre-	The CENTER-PERIPHERY	Entity	1: Existence	52: Whole

	Periphery	image schema consists of an ENTITY, a CENTRE, and a PERIPHERY (Johnson, 1987)		3: Substantiality 52: Whole 88: Unity	
			Centre	1: Existence 5: Intrisicality 30: Mean 70: Middle 74: assemblage 76: Focus 224: Interiority 225: Centrality 293: Convergence 708: Party 722: Combatant 724: Arena	
			Peripheral	10: Unrelatedness 57:Exclusion	225: Centrality

				86:Numeration 199: Distance 234: Edge 639: Unimportance	234: Edge
	Contact	The physical coming together of two or more things (ISCAT, 2012).	Contact	45: Union 202: Contiguity 272: transference 378: Touch 524: Information 529: News 588: Correspondence	45: Union
	Front-back	***FRONT***: the side that is forward or prominent; the side that is seen or that goes first ***BACK***: the side that goes last or is not normally seen; the part of something that is furthest from the normal viewer (ISCAT, 2012).	Front	64: Precedence 66: Precursor 68: Beginning 223: Exteriority 226: Covering 234: Edge 237: Front	237: Front

				281: Direction 283: Preceeding 445: Appearance 541: Falsehood 624: Way 718: War 724: Arena 878: Insolence	
			Back	218: Support 221: Inversion 227: Lining 238: Rear 240: Contraposition 282: Deviation 286: Regression 326: Hardness 352: Wind 369: Animal Husbandary	238: Rear

				605: Choice 618: Nondesign 703: Aid 784: Lending 791: Barter 923: Approbation	
	Near-far	The ***NEAR-FAR*** image schema is a topological abstraction related to the spatial proximity and distance of entities or sets of entities. The image schema ***NEAR-FAR*** can be both, static and dynamic. In the dynamic state it is concerned with approach (towards) and departure (away from) (ISCAT, 2012).	Proximity Distant	200: Nearness 202: Contiguity 19: Dissimilarity 59: Extrenousness 199: Distance 401: Faintness 444: Invisibility 454: Incuriosity 820: Insensibility 871: Pride 881: Enmity 883: Unsociability	200: Nearness 199: Distance

	Path	A ***PATH*** consists of a source or starting point, a goal or end-point, and a sequence of contiguous locations connecting the source with the goal (Johnson, 1987).	Source	68: Beginning 156: Cause 169: Parentage 350: Stream 524: Information 632: store	68: Beginning
			Goal	69: End 76: focus 145: Cessation 236: Limit 266: Quiescene 281:Direction 295: Arrival 617: Intention 859: Desire	69: End
			Path	281: Direction 297: Ingress	624: Way

				298: Egress 305: Passage 548: Record 624: Way	
	Scale	A ***SCALE*** image schema builds on the PATH image schema with added cumulativity, normativity, and fixed directionality. It is used to refer to numbers of objects, amounts of substances, degrees of force, or intensities of sensations (ISCAT, 2012; Johnson, 1987).	Scale	9: Relation 27: Degree: Relative quantity 71: Continuity 194: Receptacle 207: layer 226: Covering 229: Uncovering 308: Ascent 322: Gravity 410: Melody 421: Screen 423: Opacity 465: Measurement	27: Degree
	Verticality	This is an image schema that involves an up and down	Up	209: Height	209: Height

		relation. (Johnson, 1987; lakeoff, 1987).		215: Verticality 308: Ascent 727: Success	308: Ascent
			Down	208: Filament 210: Lowness 215: Verticality 258: Smoothness 259: Roughness 309: Descent 311: lowering 327: Softness 548: Record 772: Loss 834: Dejection 893:Sullenness	210: Lowness 309: Descent
	Rotation	A single complete turn (axial or orbital) (ISCAT, 2012).	Rotate	141: Periodicity 251: Convolution 314: Circuition	315: Rotation

				315: Rotation 318: Agitation 837: Amusement	
Multiplicity	Match	Be compatible, similar or consistent; coincide in their characteristics (ISCAT, 2012).	Match	18: Similarity 24: Agreement 28: Equality 45: Union 90:Duality 381: Heating 385: Fuel 420: Luminary 462:Comparison 716: Contention 894: Marriage	18: Similar 462: Comparison
	Link	The LINK image-schema consists of two or more entities which are connected with each other by means of a linking device of some kind (Johnson, 1987).	Entity Link	9: Relation 45: Union 47: Bond 58: Component	47: Bond

				222: Crossing 231: Interjacency	
	Part- whole	***PART-WHOLE*** is an image schema that consists of a whole, parts, and a configuration. (Lakeoff, 1987)	Whole	26: Quantify 44: Simpleness 52: Whole 54: Completeness 79: Generality 85: Number 88: Unity 646: Perfection 666: Preservation	52: Whole
			Part	46: Disunion 53; Part 55: Incompleteness 58: Component 263: Opening 294: Divergence 296: Departure	53: Part

				410: Melody 412: Music 589: Book 594: Drama 622: Business 783: Apportionment	
			Configuration	233: Outline 243: Form	58: Component 243: Form
Attribute	Big- Small	Conspicuous in position or importance, Significant (ISCAT, 2012).	Big	32: Greatness 195: Size 638: Importance 700: Difficulty 797: Money	32: Greatness 195: Size 638: Importance
			Small	33: Smallness 102: Fraction 132:Young person	33: Smallness 196: littleness

				196: Littleness 636: Insufficient 639: Unimportance 922:Contempt	639: Unimportance
	Bright dark	***BRIGHT***: emitting or reflecting light readily or in large amounts ***DARK***: devoid of or deficient in light or brightness; shadowed or black (having a dark hue when used with colours (ISCAT, 2013).	Bright Dark	417: Light 420: Luminary 425: Colour 427: Whiteness 498: Intelligence 648: Cleaness 833: Cheerfulness 841: Beauty 852: Hope 866: Repute 29: Evening 418: Darkness 425: Colour 428: Blackness	417: Light 425: Colour 418: Darkness 425: Colour

				430: Browness 439: Blindness 440: Dim sightedness 444: Invisibility 491: Ignorance 523: Latency 568: Imperspicuity 834: Dejection 893: Sullenness 930: Improbity 984: Occultism	
Force	Attraction	***ATTRACTION*** is a force image schema in which a (passive) object exerts a force on another object, either physically or metaphorically, to pull it toward itself (or in the case of ***REPULSION*** to repel it), mostly acting from a distance. (Johnson, 1987).	Attraction	76: Focus 160: Power 178: Influence 179: Tendency 291: Attraction 564: Grammer 612: Motive 826: Pleasurableness	291: Attraction

				841: Beauty 859: Desire 890: Darling 983: sorcery	
	Compulsion	***COMPULSION*** is a force image schema that involves an external force physically or metaphorically causing some passive entity to move. (Johnson, 1987).	Compulsion	503: insanity 596: Necessity 606: Absence of choice 735: Severity 737: Command 740: Compulsion 747: Restraint	740: Compulsion
	Blockage	BLOCKAGE is a force image schema in which a force / movement is physically or metaphorically stopped or redirected by an obstacle. (Johnson, 1987).	Blockage	145: Cessation 702: Hindrance	702: Hindrance
	Balance	BALANCE is a force image schema that provides an understanding of physical or	Balance	9: Relation 12: Correlation	28: Equality

		metaphorical counteracting forces: forces and/or weights counteract/balance off one another. Metaphorically, there is equilibrium, not “too much” and “not enough”. (Johnson, 1987).		24: Agreement 28: Equality 30: Mean 31: Compensation 41: Remainder 53: Part 54: Completeness 153: Stability 245: Symmentary 322: Gravity 462: Comparison 465: Measurement 498: Intelligence 502: Sanity 575: Elegance 601: Irresolution 625: Middleway 637:Redundance 823: Inexcitability	

				858: Caution	

Appendix H:

Source Code of the Algorithm that Extract Image Schema from Users' Utterances

KessPro

```
 *   21st June 2014
 *
 *
 */

#include <iostream>
#include <fstream>
#include <string>
#include <cstdlib>
#include <vector>
#include <set>
#include <map>
#include <list>
#include <locale>
#include <stdio.h>

#ifdef _WIN32
#ifndef SSCANF
//#define SSCANF sscanf_s //for visual studio
#define SSCANF sscanf //mingw
#endif
#define VASIZEOF(str) ,sizeof(str)

#else
#include <string.h>
#include <strings.h>

#ifndef SSCANF
#define SSCANF sscanf
#endif
```

```
#define VASIZEOF(str)

#endif

using namespace std;

// Read Line from text file
#define READ_IFSLINE(ifs,strformat,...) {std::string str; std::getline(ifs,str);
        SSCANF(str.c_str(),strformat, __VA_ARGS__);}

//Split token into strings
void explode(const std::string& str, std::vector<std::string>& tokens, const std::string& delimiters
        = "");
//Change to Lowercase
void strtolower(std::string &str);
//Change to Uppercase
void strtoupper(std::string &str);

struct Ontoro_type {
        int serialno;
        std::string partofspeech;
        int paragraph;
        int concept;
        int subsection;
        int section;
        int classification;
};

struct Image_schema_type {
        int klass;
        int category;
        int property;
        int conceptno;
```

```
};

void read_ontoro_database(std::multimap<std::string, Ontoro_type>& ontoro_data, const
	std::string& fname,
		const bool preprocess);

void read_input_paragraphs(std::vector<std::string>& statementlist, const std::string& fname);
void split_statement_to_tokens(std::set<std::string>& tokenslist, const std::string& statement,
		const size_t maxnumberofwordspertoken, const std::string& delim);

const std::string OUTDELIM = ",";

int main() {
	std::cout << "Hello This Kess's Program" << std::endl;

	/*
	 *
	 *  Read Ontoro Database file
	 *
	 */
	std::multimap<std::string, Ontoro_type> ontoro_data;
//	read_ontoro_database( ontoro_data, "OntoRo.txt",true);
	read_ontoro_database(ontoro_data, "OntoRo_tabbed.txt", false);

	/*
	 *
	 *  Read in Image Schema file
	 *
	 */
	std::map<int, Image_schema_type> image_concepts;
	std::ifstream ifs2;
	ifs2.open("image_schema.txt");
	if (ifs2) {
		while (ifs2) {
```

```
			Image_schema_type image;
			READ_IFSLINE(ifs2, "%i,%i,%i,%i", &image.klass, &image.category,
&image.property, &image.conceptno);
			//std::cout << klass << "\t" << category << "\t" << property << "\t" <<
conceptno << std::endl;
			image_concepts.insert(std::make_pair(image.conceptno, image));
		}
		ifs2.close();
}
/*
 *
 *   Read in Input Paragraphs from file
 *
 */
std::vector < std::string > paragraphlist;
read_input_paragraphs(paragraphlist, "input_paragraphs.txt");

//Loop over each paragraph
for (size_t it = 0; it < paragraphlist.size(); ++it) {
		/*
		 *
		 *
		 *	Process Paragraph
		 *
		 *
		 */
		std::cout << "Processing paragraph " << it + 1 << " of " << paragraphlist.size() <<
std::endl;
		//Split Paragraph Into statements
		std::vector < std::string > statementlist;
		explode(paragraphlist.at(it), statementlist, "."); //split paragraph into statements
using full stop as delimiter
		//Loop over each statement in paragraph
		for (size_t jt = 0; jt < statementlist.size(); ++jt) {
```

```
/*
 *
 *
 *    Process sentence in Paragraph
 *
 *
 *
 */
const std::string& statement = statementlist.at(jt);
std::cout << "sentence " << jt+1 << " of " << statementlist.size() << "\t\""
<< statement << "\"" << std::endl;

std::ofstream ofs_concept; //handle for concept output file
{
	char fname_concept[255];
	sprintf(fname_concept, "out_para%02i_sen%02i_concept.csv",
(int) it + 1, (int) jt + 1); //generate concept file name
	ofs_concept.open(fname_concept);
	//write headings for concept output file
	ofs_concept << "\"Count\"" << OUTDELIM << "\"Token\"" <<
OUTDELIM << "\"Concept\"" << OUTDELIM
						<< "\"Paragraph\"" <<
OUTDELIM << "\"SerialNo\"" << OUTDELIM << "\"Subsection\"" << OUTDELIM
						<< "\"Section\"" <<
OUTDELIM << "\"Classification\"\n";
}
std::ofstream ofs_image; //handle for image output file
{
	char fname_image[255];
	sprintf(fname_image, "out_para%02i_sen%02i_image.csv", (int) it
+ 1, (int) jt + 1); //generate image file name
	ofs_image.open(fname_image);
	//write headings for image output file
```

```
			ofs_image << "\"Count\"" << OUTDELIM << "\"Token\"" <<
OUTDELIM << "\"Class\"" << OUTDELIM << "\"Category\""
								<< OUTDELIM << "Property"
<< OUTDELIM << "\"ConceptNo\"\n";
		}
		/*
		 *
		 *
		 *   Split Statement Into Tokens
		 *
		 */
		std::set < std::string > tokenslist;
		split_statement_to_tokens(tokenslist, statement, 13, " ");

		size_t count_concept = 0; //initialise counter for concepts in sentence
		size_t count_image = 0; //initialise counter for images in sentence
		//Loop over each token in Sentence
		std::set < std::string > ontoro_tokenslist;
		for (std::set<std::string>::const_iterator jj = tokenslist.begin(); jj !=
tokenslist.end(); ++jj) {
			const std::string& token = *jj;
			/*
			 *
			 *   Find entries in Ontoro database that are equal to token
			 *
			 */
			std::pair<std::multimap<std::string, Ontoro_type>::const_iterator,
					std::multimap<std::string,
Ontoro_type>::const_iterator> ret = ontoro_data.equal_range(token);
			//Loop over entries in Ontoro database that are equal to token
			for (std::multimap<std::string, Ontoro_type>::const_iterator qq =
ret.first; qq != ret.second; ++qq) {
				const Ontoro_type& t = qq->second;
				//Add token to ontoro_tokenslist
```

```
                                        ontoro_tokenslist.insert(token);
                                        /*
                                         *
                                         *  Find Image Concepts that are in Ontoro database Entry
                                         *
                                         */
                                        const std::map<int, Image_schema_type>::const_iterator
pp = image_concepts.find(qq->second.concept);
                                        //Add Entry to Concept output file
                                        ofs_concept << count_concept + 1 << OUTDELIM <<
token << OUTDELIM << t.concept << OUTDELIM
                                                    << t.paragraph << OUTDELIM << t.serialno
<< OUTDELIM << t.subsection << OUTDELIM
                                                    << t.section << OUTDELIM <<
t.classification << "\n";
                                        // if concept is in Image Schema
                                        if (pp != image_concepts.end()) {
                                              const Image_schema_type& img = pp->second;
                                              //std::cout << count_image + 1 << "\t" << token <<
"\t" << qq->second.concept << std::endl;

                                              //Add Entry to Image output file
                                              ofs_image << count_image + 1 << OUTDELIM <<
token << OUTDELIM << img.klass << OUTDELIM
                                                          << img.category << OUTDELIM <<
img.property << OUTDELIM << img.conceptno << "\n";
                                              count_image++;
                                        }
                                        count_concept++;
                                  }
                            }
                            /*
                             *
                             *   Write ontoro_tokenslist to file
```

```
                    *
                    */
                    std::ofstream ofs_token;
                    {
                            char fname_token[255];
                            sprintf(fname_token, "output%02i_tokens.csv", (int) it + 1);
                            ofs_token.open(fname_token);
                    }
                    int count_token = 0;
                    ofs_token << "\"Count\"" << OUTDELIM << "\"Token\"\n";

                    for (std::set<std::string>::const_iterator jj = ontoro_tokenslist.begin(); jj !=
        ontoro_tokenslist.end();
                                    ++jj) {
                            const std::string& token = *jj;
                            ofs_token << count_token + 1 << OUTDELIM << token << "\n";
                            count_token++;
                    }
                    ofs_token.close(); //close token output file
                    ofs_concept.close(); //close concept filter file
                    ofs_image.close();
            }
        }
        return 0;
}


/*
 *
 *
 *   Split string into vector of strings using delimiter
 *
 *
 */
```

```
void explode(const std::string& str, std::vector<std::string>& tokens, const std::string&
        delimiters) {
        std::string::size_type lastPos = str.find_first_not_of(delimiters, 0);
        std::string::size_type pos = str.find_first_of(delimiters, lastPos);
        while (std::string::npos != lastPos) {
                tokens.push_back(str.substr(lastPos, pos - lastPos));
                lastPos = str.find_first_not_of(delimiters, pos);
                pos = str.find_first_of(delimiters, lastPos);
        }
        return;
}

/*
 *
 *  Convert string to lowercase
 *
 *
 */
void strtolower(std::string &str) {
        std::locale loc;
        for (size_t i = 0; i < str.length(); i++) //This makes sure that we get the whole word.
                if (str[i] >= 'A' && str[i] <= 'Z') //90 is the value for "Z".
                str[i] = std::tolower(str[i], loc); //32 is the difference between an uppercase and its
        lower counterpart
        return;
}


/*
 *
 *  Convert string to uppercase
 *
 *
 */
```

```
void strtoupper(std::string &str) {
	std::locale loc;
	for (size_t i = 0; i < str.length(); i++) //This makes sure that we get the whole word.
		if (str[i] >= 'a' && str[i] <= 'z') //97 is the value for "a" 122 = z.
		str[i] = std::toupper(str[i], loc); //32 is the difference between an uppercase and its
	lower counterpart
	return;
}

/*
 *
 *   Read Ontorodase file
 *
 *
 */
void read_ontoro_database(std::multimap<std::string, Ontoro_type>& ontoro_data, const
	std::string& fname,
		const bool preprocess) {
	std::string fname2 = "OntoRo_tabbed.txt";
	if (preprocess) {
		const std::string cmd = "cat " + fname
				+ " | awk 'BEGIN{FS=\",\";OFS=\"\t\"} {print $1,$2,$3,$5,$6,$7,$8 ;
	print $4}' > " + fname2;
		system(cmd.c_str());
	} else {
		fname2 = fname;
	}

	std::ifstream ifs1;
	ifs1.open(fname2.c_str());
	if (ifs1) {
		while (ifs1) {
			Ontoro_type t;
			std::string word;
```

```
                char tempstr1[255];
                READ_IFSLINE(ifs1, "%i\t%s\t%i\t%i\t%i\t%i\t%i",
                        &t.concept, tempstr1, &t.paragraph, &t.serialno,
        &t.subsection, &t.section, &t.classification);
                t.partofspeech = tempstr1;
                std::getline(ifs1, word);
                strtolower(word);
                ontoro_data.insert(std::make_pair(word, t));
            };
            ifs1.close();
        }
        return;
}


/*
 *
 *   Read paragraphs from file
 *
 *
 */
void read_input_paragraphs(std::vector<std::string>& paragraphlist, const std::string& fname) {
        std::ifstream ifs;
        ifs.open(fname.c_str());
        if (ifs) {
            while (ifs) {
                std::string paragraph;
                std::getline(ifs, paragraph);
                strtolower(paragraph);
                if (paragraph.size() > 0) paragraphlist.push_back(paragraph);
            }
            ifs.close();
        }
        return;
```

```
}

/*
 *
 *   Split statement into tokens
 *
 *
 */
void split_statement_to_tokens(std::set<std::string>& tokenslist, const std::string& statement,
                const size_t maxnumberofwordspertoken, const std::string& delim) {
        //const int maxnumberofwordspertoken = 13;
        std::vector < std::string > singletokens;
        explode(statement, singletokens, delim);
        //Insert Single tokens into set
        for (int j = 0; j < singletokens.size(); j++) {
                std::string str = singletokens.at(j);
                tokenslist.insert(str);
                for (int k = j + 1; k < j + maxnumberofwordspertoken && k < singletokens.size();
        ++k) {
                        str += " " + singletokens.at(k);
                        tokenslist.insert(str);
                }
        }
        return;
}
```

Appendix I:

Affective Words Linked to the Image Schema Used in Study 3

Table I.1: Affective Words Linked to the Image Schemas used in Study 3 for product 1

Participants	Task related words	Concept number	Image schemas extracted	Afective words		No match
				Positive	Negative	
1	Features	58, 243	Part-whole	-	Confusing	
	Component	58	Part-whole	-	-	Button
	Press	740	Compulsion	-	-	
	Mode	624	Path	-	Difficult	
	Colour	417, 425	Bright-dark	-		
	Up	209, 308	Up-down	-		
	Increase	308	Up-down	-		
2	Mode	624	Path	-	-	
	Press	740	Compulsion	-	-	Blinking, Push
	Match	18, 462	Match	-	-	
	Down	210, 309	Up-down	-	Uncomfortable	
	Up	209, 308	Up-down		-	
3	Press	740	Compulsion	-	-	
	Into	224	Container, content	-	-	Arrow
	Up	209, 308	Up-down	-	Unexpected	

	Arrangement Increase	243 308	Part-whole Up-down	Lovely -	- Unexpected	
4	Into Up Down Press	224 209, 308 210, 309 740	Container, Content Up-down Up-down Compulsion	Easy Nice - -	- -	 -
5	Mode Press Colour Up Down Increase	624 740 417, 425 209,308 210, 309 308	Path Compulsion Bright-dark Up-down Up-down Up-down	- - - - - -	Difficult - Poor - - -	 -
6	Part Like Press Mode Up	53, 58 18 740 624 209,308	Part-whole Match Compulsion Path Up-down	- Good - - -	- - - - Weird	 Change, Icon

7	Into Mode Press Colour Up	224 624 740 417, 425 209,308	Container, content Path Compulsion Bright-dark Up-down	- - - - -	- - - - Confusing	 Changing
8	Part Mode Press Up Set	53, 58 624 740 209,308 58	Part-whole Path Compulsion Up-down Part-whole	- - - - -	Tough Disapointed - Unfamiliar -	 Change
9	Up Down Press Mode. Match Set	209, 308 210, 309 740 624 18 58	Up-down Up-down Compulsion Path Match Part-whole	- - - - Obvious -	Confusing - - - - -	 Cycle, Push, button
10	Component	58	Part-whole	Explicit Confident	- -	 -

	Into	224	Container, Content	-	-	
	Mode	624	Path		Challenging	
	Up	209, 308	Up-down	-	-	
	Press	740	Compulsion	-	-	
	Down	210, 309	Up-down	-	-	
	Set	58	Part-whole	-	-	
11	Press	740	Up-down		Strange	
	Mode	624	Path	-	Hard	Symbol, Alarm, Clock
	Down	210, 309	Up-down		Confusing	
	Set	58	Part-whole			
12	Press	740	Compulsion			
	Mode	624	Path		Difficult	
	Colour	417, 425	Bright-dark		Bad	
	Up	209, 308	Up-down			
	Set	58	Part-whole			
13	Press	740	Compulsion		Funny	
	Mode	624	Path		Challenging	Changing,
	Up	209, 308	Up-down			

	Set	58	Part-whole			
14	Mode	624	Path	Easy		Time
15	Mode	624	Path	Familiar		
	Press	740				Change
	Set	58	Compulsion			
			Part-whole			
16	Into	224	Container, Content		Difficult	
	Mode	624	Path		Challenging	button,
	Press	740	Compulsion			
17	Parts	53, 58	Part-whole	Compatible		
						Button, Time
	Press	740	Compulsion			
	Direction	624	Path			
	Back	238	Front-back			
	Front	237	Front-back			
	Increase	308	Up-down		Unexpected	
18	Press	740	Compulsion			
	Enter	297	Container, Content			-

	Mode Up Down Set	624 209, 308 210, 309 58	Path Up-down Up-down Part-whole		Complicated Bad	
19	Press Up Down Set	740 209, 308 210, 309 58	Compulsion Up-down Up-down Part-whole		Confusing	Button
20	Into Mode Light Press	24 624 417, 425 740	Container, Content Path Bright-dark Compulsion	Comfortable	Frustrating	Alarm
21	Mode Press Down	624 740 210, 309	Path Compulsion Up-down		Problematic Confusing	Change, Button
22	Mode Press Up	624 740 209, 308	Path Compulsion Up-down		Difficult	Change, button

	Set	58	Part-whole			
23	Mode Press Up Set	624 740 209, 308 58	Path Compulsion Up-down Part-whole	Beautiful	Difficult Awful	-
24	Up Increase Set	209, 308 308 58	Up-down Up-down Part-whole		Difficult Problematic	Change, Button
25	Mode Press Colour Match	624 740 417, 425 18	Path Compulsion Bright-dark Match	Nice	Inconvenient	Icon, Button
26	Press Down Colour Set	740 210, 309 417, 425 58	Compulsion Up-down Bright-dark Part-whole		Confusing Distracting	Blinking

27	Enter	297	Container, Content	Helpful		
	Mode	624	Path	Familiar	Uncertain	-
	Down	210, 309	Up-down			
	Press	740	Compulsion			
28	Mode	624	Path			
	Press	740	Compulsion			Button, Indicator
	Colour	417, 425	Bright-dark		Confusing	
	Up	209, 308	Up-down			
	Down	210, 309	Up-down			
29	Press	740	Compulsion			
	Up	209, 308	Up-down			Side
	Down	210, 309	Up-down			
	Parts	53, 58	Part-whole		Complex	
	Set	58	Part-whole			
	Increase	308	Up-down		Strange	
30	Colour	417, 425	Bright-Dark		Hard	Colour
31	Parts	53, 58	Part-whole		Problem	

	Mode Up Down Increase Set	624 209, 308 210, 309 308 58	Path Up-down Up-down Up-down Part-whole		Challenging Amaze hard	-
32	Press Up Down	740 209, 308 210, 309	Compulsion Up-down Up-down		Dislike	Button
33	Mode Press Down Arrangement	624 740 210, 309 243	Path Compulsion Up-down Part-whole		Surprising	-
34	Parts Mode Press Into Down	53, 58 624 740 224 210, 309	Part-whole Path Compulsion Container, content Up-down	Clear		Change

	Colour	417, 425	Bright-dark		Poor	
35	Press	740	Compulsion			
	Up	209, 308	Up-down		Wondering	Button
	Set	58	Part-whole			
36	Press	740	Compulsion			
	Up	209, 308	Up-down		Disagree	Buttons
	Down	210, 309	Up-down			
	Increrase	308	Up-down			
	Set	58	Part-whole			
37	Press	740	Compulsion			
	Up	209, 308	Up-down		Weird	Blinking
	Down	210, 309	Up-down			
	Mode	624	Path			
	Set	58	Part-whole			
	Increase	308	Up-down			
	Colour	417, 425	Bright-dark		Unpleasant	
38	Enter	297	Container, content			
	Mode	624	Path			-

39	Into Mode Press. Up Down	224 624 740 209, 308 210, 309	Container, Content Path Compulsion Up-down Up-down			right, Left
40	Up Press Into Mode Match Set	209, 308 740 224 624 18 58	Up-down Compulsion Container, content Path Match Part-whole	Good Attractive		Button.

Table I.2: Affective Words Linked to the Image Schemas used in Study 3 for product 2

Participants	Task related words	Concept number	Image schemas extracted	Affective words		No match
				Positiv e	Negative	
1	Press Colour	740 417, 425	Compulsion Bright-dark	Instinctive		Key
2	Mode Press	624 740	Path Compulsion		Tricky, non-intuitive	Symbol, Push
3	Arrangement Feature Switch Press Move Into Mode Represent	243 58, 243 53 740 297 624 18	Part-whole Part-whole Part-whole Compulsion Container Path Matching	Lovely	Unexpected Difficult	Button changing

4	Press Mode Into	740 624 224	Compulsion Path Container, Content		Difficult	Alarm,
5	Enter Mode Press	297 624 740	Container, Content Path Compulsion	Nice Easy	Frustrating	-
6	Press Parts Enter Mode	740 53, 58 297 624	Compulsion Part-whole Container, Content Path	Simple	Terrible	-
7	Features Press Get into	58, 243 760 297	Part-whole Compulsion Container, Content	Classical		-
8	Up Down Press Mode	209, 308 210, 309 740 624	Up-down Up-down Compulsion Path		Clear	Change, Sign,

	Switch	53	Part-whole		complicated	
9	Press Mode Switch	740 624 53	Compulsion Path Part-whole	Prefer	Difficult	-
10	Press Mode Into	740 624 224	Compulsion Path Container, Content		Challenging strange	-
11	Mode Press	624 740	Path Compulsion		Difficult	-
12	Press Mode	740 624	Compulsion Path	Good	confusion	Push, Symbol, button
13	Press Mode	740 624	Compulsion Path		Tough	
14	Features	58, 243	Part-whole		Useless	-
15	Features Mode	58, 243 624	Part-whole Path	Simple Fine		Alarm,

	Press	740	Compulsion		Challenging	
16	Draw Mode	291 624	Attraction Path	Fascinatin g -		Symbol,
17	Features	58, 243	Part-whole	Explicit	Challenging	-
18	Parts Set Down Light	53, 58 58 210, 309 417, 425	Part-whole Part-whole Up-down Bright-dark	Appealing Like		Symbol, key, blinking
19	Direction Turn	624 315	Path Rotation		Complex Unexpected	-
20	Press Up Set Process	740 209, 308 58 624	Compulsion Up-down Part-whole Path		Tough	Alarm, Button
21	Press Direction	740 624	Compulsion Path		Challenging Difficult	Buttons,

22	Features Press Description	58, 243 740 18	Part-whole Compulsion Matching	Interesting Easy		-
23	Press Mode Set Features	740 624 58 58, 243	Compulsion Path Part-whole Part-whole	Simple		-
24	Features	58, 243	Part-whole	Simple Attractive		--
25	Press	740	Compulsion		Frustrating	-
26	Press	740	Compulsion		T ough Confusing	Symbol, Changing
27	Features Press	58, 243 740	Part-whole Compulsion	Nice		Change, Button
28	Press	740	Compulsion	Simple		-
29	Mode Press	624 740	Path Compulsion		Incompatibl e	Product, Change, Symbol

	Set	58	Part-whole			
30	Press	740	Compulsion		Challenging Weird	-
31	-	-	-			Symbol
32	Press Get into	740 297	Compulsion Container, Content	 Good		-
33	Press Mode Light	740 624 417, 425	Compulsion Path Bright-dark	 Percieved 	 Bad	-
34	Mode Press Turn	624 740 315	Path Compulsion Rotation		Challenging	Button, Turn
35	Mode Press Up Down	624 740 209, 308 210, 309	Path Compulsion Up-down Up-down	Familiar		 Symbol
36	Turn	315	Rotation			Alarm
37	Press	740	Compulsion		Unexpected	Changing,

	Down Colour	210, 309 417, 425	Up-down Bright-dark			
38	Features	58, 243	Part-whole			Features
39	Press Mode	740 624	Compulsion Path		Complicated Strange	Changing, Button, Symbol
40	Parts Press	53, 58 740	Part-whole Compulsion	Good		-

Appendix J:

Affective Words Identified in Study 3

Table J.1: Affective Words Identified in Study 3

S/n	Affective word	Affect category (GALC)	Valence
1	Amaze	Surprise	Negative
2	Appealing	Pleasurable/Enjoyment	Positive
3	Attractive	Longing	Positive
4	Awful	Irritation	Negative
5	Awkward	Tension/stress	Negative
6	Bad	Negative	Negative
7	Beautiful	Pleasurable/enjoyment	Positive
8	Challenge	Negative	Negative
9	Classical	Positive	Positive
10	Clear	Feeling	Positive
11	Comfortable	Contentment	Positive
12	Compatible	Positive	Positive
13	Complex	Tension/stress	Negative
14	Complicated	Tension/stress	Negative
15	Confident	Hope	Positive
16	Confusing	Tension/stress	Negative
17	Difficult	Tension/stress	Negative
18	Disagree	Tension/stress	Negative
19	Disappointed	Disappointment	Negative
20	Discomfort	Tension/stress	Negative
21	Disliked	Disgust	Negative
22	Distracted	Irritation	Negative
23	Easy	Feeling	Positive
24	Expected	Positive	positive
25	Explicit	Positive	Positive
26	Familiar	Positive	Positive
27	Fascinated	Admiration	Positive
28	Feel	Feeling	Positive
29	Fine	Positive	Positive
30	Frustration	Disappointment	Negative
31	Funny	Amusement	Positive
32	Good	Positive	Positive
33	Hard	Tension/stress	Negative

34	Helpful	Positive	Positive
35	Incompatible	Negative	Negative
36	Instinctive	Feeling	Positive
37	Interest	Interest	Positive
38	Intuitive	Feeling	Positive
39	Like	Feeling	Positive
40	Lovely	Pleasure/Enjoyment	Positive
41	Nice	Pleasurable/enjoyment	Positive
42	Obscure	Tension/stress	Negative
43	Obvious	Positive	Positive
44	Perceived	Feeling	Positive
45	Poor	Negative	Negative
46	Preferable	Positive	Positive
47	Problematic	Tension/stress	Negative
48	Satisfying	Contentment	Positive
49	Simple	Feeling	Positive
50	Strange	Surprise	Negative
51	Surprising	Surprise	Negative
52	Terrible	Tension/stress	Negative
53	Tough	Tension/stress	Negative
54	Tricky	Tension/stress	Negative
55	Uncertain	Negative	Negative
56	Uncomfortable	Tension/stress	Negative
57	Unexpected	Surprise	Negative
58	Unfamiliar	Negative	Negative
59	Unpleasant	Irritation	Negative
60	Useful	Feeling	Positive
61	Useless	Negative	Negative
62	User friendly	Feeling	Positive
63	Weird	Surprise	Negative
64	Wish	Longing	Positive
65	Wondering	Admiration/Awe	Negative

Appendix K: 'Q' Value Computed for each Image Schemas Used in Study 3

Table K.1: 'Q' scores for the image schemas used for product 1

Participants	Up- down, %	Part-whole, %	Attraction, %	Path, %	Container, %	Matching, %	Near–far, %	Bright –dark, %	Compulsion, %
1	40.25	100.00	55.65	45.20	100.00	41.00	38.55	33.85	100.00
2	42.35	100.00	45.80	35.65	100.00	28.45	58.25	52.80	100.00
3	36.45	100.00	23.80	23.50	100.00	16.20	35.42	42.35	100.00
4	30.78	100.00	20.42	20.62	100.00	18.45	32.45	45.20	100.00
5	35.50	100.00	43.10	36.40	100.00	56.21	28.28	43.80	100.00
6	50.20	100.00	65.30	65.20	100.00	60.20	60.20	72.35	100.00
7	32.30	100.00	24.55	28.65	100.00	15.20	32.75	36.20	100.00
8	24.40	100.00	36.45	18.50	100.00	18.60	30.55	32.55	100.00
9	30.65	100.00	30.80	16.25	100.00	12.73	35.85	35.85	100.00
10	50.20	100.00	30.60	42.35	100.00	44.25	26.50	46.55	100.00
11	40.25	100.00	36.50	33.85	100.00	30.20	45.20	45.45	100.00
12	26.55	100.00	22.35	15.20	100.00	16.20	30.70	45.25	100.00
13	65.80	100.00	56.25	62.50	100.00	67.50	65.35	70.20	100.00
14	62.25	100.00	60.75	60.20	100.00	53.65	63.80	68.70	100.00
15	72.35	100.00	75.80	50.20	100.00	68.80	64.25	63.75	100.00
16	25.85	100.00	23.65	20.20	100.00	30.55	28.42	40.25	100.00
17	30.30	100.00	18.25	27.70	100.00	22.35	33.85	31.25	100.00
18	66.70	100.00	56.20	58.80	100.00	70.25	58.25	68.25	100.00
19	72.35	100.00	60.45	50.20	100.00	63.25	65.65	58.20	100.00
20	35.35	100.00	40.20	40.25	100.00	36.28	45.35	40.25	100.00
21	64.50	100.00	70.25	58.20	100.00	60.25	71.35	66.80	100.00
22	60.25	100.00	58.25	62.35	100.00	73.20	63.50	50.25	100.00
23	50.25	100.00	46.50	36.25	100.00	52.35	22.55	42.35	100.00
24	24.55	100.00	25.65	32.45	100.00	15.22	40.25	26.55	100.00
25	73.20	100.00	62.30	50.20	100.00	53.25	64.50	70.25	100.00
26	68.35	100.00	73.25	55.55	100.00	57.45	70.25	59.35	100.00
27	52.50	100.00	33.85	40.20	100.00	36.25	30.60	46.20	100.00
28	36.80	100.00	32.55	30.50	100.00	42.80	40.60	43.55	100.00
29	38.25	100.00	30.60	40.60	100.00	28.25	43.80	40.20	100.00
30	22.87	100.00	35.65	25.60	100.00	20.20	40.45	14.25	100.00

Table K.2: 'Q' scores for the image schemas used for product 2

Participants	*Up- down, %*	*Centre-periphery*	*Attraction, %*	*Path, %*	*Container*	*Matching, %*	*Bright –dark, %*	*Compulsion, %*
1	36.80	100.00	35.50	30.55	100.00	38.20	45.50	100.00
2	32.38	100.00	28.65	22.35	100.00	30.65	20.45	100.00
3	70.15	100.00	55.80	66.35	100.00	60.20	65.50	100.00
4	69.95	100.00	60.20	56.80	100.00	63.20	72.45	100.00
5	52.85	100.00	45.65	30.20	100.00	42.65	50.40	100.00
6	35.85	100.00	20.20	18.25	100.00	26.25	25.35	100.00
7	66.80	100.00	50.25	73.60	100.00	65.20	64.25	100.00
8	16.85	100.00	15.25	21.35	100.00	32.40	32.25	100.00
9	60.20	100.00	60.25	64.35	100.00	68.20	68.85	100.00
10	15.50	100.00	22.35	28.65	100.00	35.20	30.45	100.00
11	22.65	100.00	30.25	15.35	100.00	28.45	26.40	100.00
12	50.25	100.00	35.50	30.80	100.00	43.55	55.65	100.00
13	28.60	100.00	20.20	28.50	100.00	25.25	30.50	100.00
14	15.20	100.00	30.30	23.50	100.00	26.50	26.55	100.00
15	36.85	100.00	38.65	46.50	100.00	40.50	40.75	100.00
16	56.28	100.00	60.25	65.50	100.00	62.35	70.30	100.00
17	26.25	100.00	18.75	15.25	100.00	28.55	35.30	100.00
18	47.75	100.00	30.00	41.75	100.00	50.20	70.85	100.00
19	40.55	100.00	40.25	45.35	100.00	30.85	43.20	100.00
20	52.35	100.00	28.65	42.35	100.00	46.72	40.40	100.00
21	56.25	100.00	56.80	73.45	100.00	65.25	63.20	100.00
22	56.20	100.00	63.55	62.20	100.00	68.70	72.25	100.00
23	45.35	100.00	22.35	45.65	100.00	52.15	56.80	100.00
24	73.25	100.00	52.30	63.70	100.00	70.25	68.30	100.00
25	38.15	100.00	33.50	48.25	100.00	40.95	42.35	100.00
26	60.70	100.00	63.50	65.80	100.00	62.20	58.35	100.00
27	38.65	100.00	20.65	28.85	100.00	16.20	30.65	100.00

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