# Linking Design Intention and Users' Interpretation through Image Schemas

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**Abstract:** Usability is often defined as the ease of use of a product but this definition does not capture other important characteristics related to the product design as being effective, efficient, engaging, error-free and easy to learn. Usability is not only about measuring how people use a product but more importantly, it is about exploring the relationship between how designers have intended their products to be used and how users interpret these designs. Previous research has shown the feasibility of using image schemas to evaluate intuitive interactions. This paper extends previous research by proposing a method, which uses image schemas to evaluate usability by measuring the gap between design intention and users' interpretations of the design. The design intention is extracted from the user manual while the way users interpret the design features is captured using direct observation, think aloud protocol and a structured questionnaire. The proposed method is illustrated with a case study involving 42 participants. The results show close correlation between usability and the distance between design intent and users' interpretation.

*Keywords:* Image Schemas, Usability, Performance evaluation, User study, Product Design.

## 1. INTRODUCTION

It was once estimated that each person in the Western world uses some twenty thousand different objects, 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). The correct interpretation of the product features is even more challenging for the users when several technologies are employed in the same device. Over the last decade, this problem has been aggravated due to market demand and high consumer expectations.

The importance of relating intention to interpretation has been recognised as a research problem but the relationship between how designers intend products to be used and how they are subsequently interpreted has been regarded as a communication issue (Crilly et al., 2008).

Traditionally, the use of image schemas has been advocated as an approach for exploring user centred design (Hurtienne, 2011; Maracanas et al., 2012). An image schema is a recurring structure within the human cognitive system that establishes patterns of reasoning with the physical world (Johnson, 1987). The theory originates from cognitive linguistics and is linked to metaphors (Johnson, 2012). Recently, image schemas have been found useful in capturing interactions with products and analysing product features. Examples of products used in usability studies include cameras (Kuhn and Frank, 1991), airplane cockpits (Hurtienne, 2011), mobile phones (Britton et al., 2013) and alarm clocks (Asikhia et al., 2015). The methods used to analyse the interactions include direct observation (Antle et al., 2011; Britton et al., 2013) and 'think aloud' protocol (Maglio and Matlock, 1999; Hurtienne and Langdon, 2010).

This paper extends previous research by proposing a method, which uses image schemas to evaluate usability by measuring the distance between the designer and user mental models, i.e. the gap between design intention and user's interpretation. A user's mental model in this context is the understanding the user develops of how the system operates or is used. On the other hand, the mental model of the designer is his/her expectation of how the product should be used. A good understanding of the gap between design intention and user's interpretation of design features could lead to significant improvements in usability. The main hypothesis in this paper is that both design intention and user interpretation could be expressed through image schemas, and the gap between them can be measured by exploring how the intended image schemas are used.

The remainder of the paper is organised as follows. Section 2 discusses product usability and image schemas. Section 3 introduces the approach developed, which is then illustrated in Section 4 using a case study. The results are discussed in Section 5. Finally, Section 6 concludes the paper.

## 2. LITERATURE REVIEW

### 2.1 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, 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. Therefore, product design can be discussed in terms of designer's implementation and representation, and user's mental model (Cooper et al., 2014). The implementation model typifies the designer's idea, while the representation model is the embodiment of that idea in the product. The user's model is their understanding of how the product operates. Users normally do not have access to the designer's intent and often their interpretations are based on previous experiences with similar products.

Previous research (Norman, 1988; Giard, 1989; Mono, 1997; Muller, 2001; Crilly et al., 2004, 2008) has studied the relationship between designer's intention and user's interpretation. In this context, the design intent refers to how a product is to be experienced, while the user interpretation is based on how the product is actually perceived. Designers develop their 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 (Hekkert, 2006; Desmet and Hekkert, 2007). In particular, the experience of meaning is linked to cognition; where image schemas play an important role in the process of 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 used to describe these experiences (Kuhn, 2007, Hurtienne et al., 2008).

### *2.2 Image Schemas*

An image schema is a dynamic pattern of organism- An image schema is a dynamic pattern of organism-environment interaction that gives understanding to an experience emanating from human bodily interaction with the physical world (Johnson, 1987; 2012). For example, the verticality schema provides a basis for the up-down orientation based on different experiences such as perceiving a tree, felt sense of standing upright, the activity of climbing stairs, forming a mental image of a flagpole, measuring children's height and experiencing of water rising in a bathtub (Johnson, 1987). These 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 it. 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). Other frequently used schemas include *near-far*, *big-small*, and *front-back*.

Forty-two image schemas, divided into eight groups, with over 250 metaphoric extensions have been tested and validated in linguistic studies (Lakoff and Johnson, 1980; Johnson 1987; Hampe, 2005; Hurtienne, 2011). 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.

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.

Traditionally, the use of image schemas and their metaphoric extensions has been advocated in user centred design (Hurtienne and Blessing, 2008; Hurtienne and Langdon 2010). Image schemas occupy sensorimotor level in the continuum of knowledge acquired before interaction (Hurtienne and Blessing, 2007). Therefore, a product feature designed with the knowledge of image schemas is more likely to require less cognitive effort to understand its operation. Several studies have focused on the use of image schemas in usability studies. These studies show that image schemas can be used in analysing the steps involved in interactions with products (Hurtienne et al., 2008), product descriptions (Maglio and Matlock, 1999; Hurtienne and Israel, 2007), direct observations (Britton et al., 2013) and utterances (Hurtienne and Langdon, 2010). The image schemas identified and extracted in these studies have been used to improve the usability and redesign the products.

The findings in the previous studies have a number of implications in product design. 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 evaluating product usability.

## 3. PROPOSED APPROACH

This research proposes the use of image schema as a means of representing designers' intent and users' interpretation based on their interactions with a product. Fig. 1 shows the conceptual model of the proposed method, which compares how designers intend a product to be used and how it is subsequently experienced by the users.


Fig. 1 Conceptual Model of the Proposed Method

The designer's intent is extracted manually from the description of the product features and the operation steps in the user manual. The user interpretation is captured using direct observation, think aloud protocol and a structured questionnaire. The direct observation and think aloud studies of the participants are recorded and transcribed, after which the data is analysed carefully and the image schemas attempted or used are extracted. Thereafter a structured questionnaires is presented to the participants to rate their preference in terms of the appearance (size, colour and icon) and spatial location of the features. A five-point Likert scale is employed. The preference rating extracted from the structured questionnaire is then used as a means of measuring the distance between the designers' intent and users' interpretation during the interaction. The participants' preference rating is compared against a benchmark rating of 5, which is considered to be the intended use according to the designer. The difference between the intended benchmark rating and the participants rating is used to calculate the distance between the designer intent and user interpretation.

This study focuses on image schema used to represent product form. The clarity of the outward appearance of the product feature (form) can greatly improve the interpretation that the users develop on how the product functions (Demirbilek and Sener, 2003). The experience of meaning can be appreciated in terms of, for example, colour, shape, size, texture, icon and spatial location of the features. These aspects represent the product form. For example, the size of the feature can be represented with the *big-small* image schema; the colour of the feature can be represented with the *bright-dark* and *attraction* image schemas; the icon can be represented with *matching* image schema; while the spatial location of the feature can be used to represent *centre-periphery, up-down, near-far* and *front-back* image schemas.

## 4. CASE STUDY

The proposed approach is evaluated through a case study involving forty-two participants completing a set task with an alarm clock. A pre-screening questionnaire was used to recruit the participants from a pool of volunteers. The participants were 13 females, age range from 22 to 43 years, and 29 males, age range from 22 to 45 years. None of the participants had prior experience with the product used in the study.

A multi-functional alarm clock was used in the experiments. The alarm clock has seven features including time, alarm, minute, hour, snooze button, alarm switch and display. These features are common to most digital clocks. The product was chosen for the study because it provided many interaction opportunities based on a wide range of image schemas.

Fig. 2 shows the product used in the study. The design of the clock consists of a bright colour 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 minute button from 5 to 11 a.m. Similarly, to set the minutes, the user holds the alarm button while pressing the minute button from 0 to 30.


Fig. 2. Alarm Clock Used in the Study.

The equipment used in the study comprised:

(1) Four digital cameras. These cameras recorded participant's interactions from four angles.
(2) Noldus Observer XT software. Observer XT is the software for capturing, analysing and presenting behavioural data (Noldus, 2010).

The equipment used in the study was explained to the participants prior to the start of the study.

The image schemas required to complete each subtask were identified based on the product documentation. This information represents the knowledge required to complete the subtask based on designers' perspective. The knowledge used during the interactions by the participants to complete the subtask was identified using direct observation and think aloud protocol.

The participants were given a task to set the normal time to 11.30am. The task was set by the researcher, who, in preparation for the experiments, carefully explored and analysed the possible paths for actualising the task that could be followed by the users. The participants were asked to figure out how to complete the task without consulting the manual. The task consisted of a sequence of three subtasks extracted from the product manual:

(i) Activate the time mode,
(ii) (ii) Set the hour mark, and
(iii) (iii) Set the minute mark.

Prior to the start of the experiment, the clock was in an alarm mode with the time set to 3.00 a.m. The participants were timed and observed during the task; all interactions were recorded. Next, the participants rated their preferences using a structured questionnaire. Finally, an exit interview was conducted. The study lasted approximately fifteen minutes per participant.

The users' interactions were recorded using the two methods mentioned earlier: direct observation and think aloud protocol as shown in Table 1. The video recordings were subsequently used to produce a transcript of the interactions of each participant while completing the task for all three subtasks. For this participant, based on his direct observation data, associating the text written close to the feature by searching for the switch controlling the alarm and time mode activated the *near-far* image schema while the indication on the screen instantiated the *matching* image schema.

For the think aloud data, distinguishing between the 'normal' and the 'alarm' time, which the participants claim he did not 'see anything that represents time mode' instantiated the *matching* image schema. The appearance of the feature activated the *centre-periphery* image schema while the big snooze button activated the *big-small* image schema.

**Table 1. An Example of the Interactions of a Participant**

| 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 (**Near-far image schema)** 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 (**Matching image schema**). | *'I have to search carefully to know where to begin. The arrangement of the feature is lovely (***Centre-periphery, Near-far image schemas***). Okay. I have seen the switch and the big snooze buttons. I have to press the switch forward to move into "time" mode. I can't really see anything that represents "time" mode (***Matching image schema***). 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 (**Near-Far and Centre- periphery image schemas**). | *'I have pressed almost all the buttons and nothing seems to be changing. It keeps blinking* **(Attraction image schema).** *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 (Near-far image schema). 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'.* |

The image schemas identified and extracted both from the designer's perspective and users' interaction for the product used in the study were collated and analysed by the experimenter.

Thereafter, the image schemas envisaged for the completion of the task from the designer's perspective were compared with the image schemas employed in the completion of the task by the users. This comparison produces a measure of the distance between the designer's intent and the user's interpretation. It is expected that the closer the gap between the designer's intention and user's interpretation based on image schemas, the higher the chances that there will be significant improvements in usability of the product.

## 5. RESULTS AND DISCUSSIONS

### *5.1 Results*

The participant's preference ratings of the image schemas representing the product form used for the interaction is shown in Fig. 3. As mentioned earlier, the preference ratings was used as a means of measuring the distance between the designer's intent and user's interpretation. The study focuses on the image schemas used to represent the product form. These comprises colour, shape, size, texture, icon and spatial location of the features. The analysis of the image schemas used by the participants for the interaction was conducted. The result reveals a high preference ratings compared to the intended (rating 5) of four out of the six image schemas used in completing the task by the participants. These include 3.6 for *big-small*, 4.2 for *bright-dark*, 4.0 for *attraction,* and 3.8 for *near-far*. While the *matching* and *centre-periphery* image schemas have a low rating of 2.2 and 1.8 respectively compared to the intended rating of 5 in the study. These two image schemas was observed to be responsible for the task difficulties experienced by the majority of the participants in the study.

The results in the study reveal close correlation between usability and the distance between design intent and users' interpretation during the interactions.

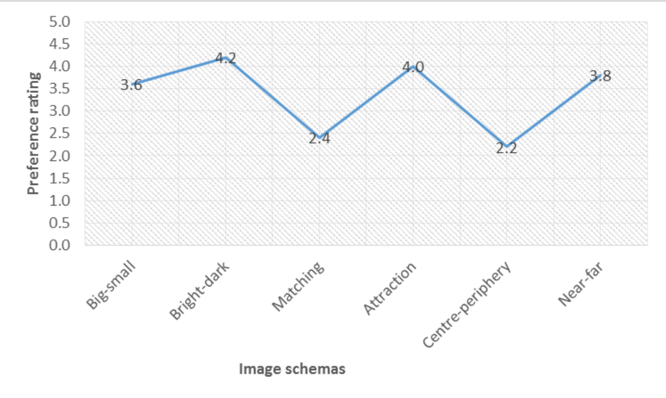


Fig. 3. Preference Ratings of the Participants

*5.2 Discussion*

The approach used in the study identified that users experienced difficulties while interacting with the product. For example, the two image schemas (with low preference ratings) responsible for many difficulties appear to correlate closely with the data collected through direct observation and think aloud data. For example, the position of the screen and the five buttons controlling the alarm clock instantiated the *centre-periphery* image schema. The five buttons controlling the alarm clock were placed at the top, while the screen located in front of the product created interaction difficulties for the majority of the participants. The majority of the participants in the study affirmed that they had problems coordinating their hand and eye movement while using the features located in these respective positions in the product. It was very difficult for the participants to combine the two buttons (time and hour buttons) placed at the top of the product to set the time and equally also observe the information on the screen in front of the product while completing the task. This difficulty resulted in more errors and longer time taken by the participant while completing the task. To address this difficulty, based on the overwhelming preference of the participants in the study, it is recommended to provide a simple interaction (single button press) placed at both sides of the screen of the product. Similarly, the *matching* image schema affected the majority of the participants in terms of the presentation of the icon used to represent the time mode. The 'dot' symbol was used as an icon to represent the 'normal' time mode by the designer, 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 but their knowledge did not match what was represented in the design. The 'dot' symbol used by the designer to represent the time mode clearly made no sense to the users. The majority of the participants affirmed that they noticed the 'dot' symbol but did not understand what it represented. Similarly, providing a better icon preferably a bell would have be more meaningful to the users in the context of the interaction than a 'dot' symbol used to represent the time mode for the product used in the study.

## 6. CONCLUSIONS

The results presented in the study suggest that the proposed approach can be used to analyse any user interface element. The effect of the identified image schemas on the interface features can be described based on the approach. If the effects are not those that are intended by the designer, changes can be recommended in order to improve the interpretation of the product features by the users and the intuitiveness of the product design.

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.

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