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Semiotic Perception of Signs in Web Interfaces on Mobile Devices

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Signs and icons are a part of user interfaces (UIs) that are both designed for and mediated between humans and mobile devices in order for users to achieve tasks. Users act on signs as a result of their comprehension of a sign's content. Meaningful signs improve users' comprehension. The study of signs and its meaning- semiotics – has been used in HCI to improve the usability of systems. Signs appear in many different contexts, and their interpretation varies between contexts. One increasingly prevalent context is mobile devices, but there is scant knowledge of how the interpretation of signs is affected by small displays and other mobile limitations. We propose a study for determining the influence of mobile devices on the interpretations of icons and signs by users. This study focuses on the impact of interaction sequences on the accuracy of user interpretations of signs, as series of displays are often used instead of large one-screen interfaces in mobile interfaces.

Semiotics, Mobile Context, User Interface, Signs, User's Interpretation, Sequence of Interaction, Usability

1. INTRODUCTION

Mobile devices can be defined according to the services they provide, and the functions attached to them [1]. Sharp et al [2] defined mobile devices as systems that are handheld and intended to be used while on the move.

With the rising ubiquity of mobile smartphones, improving the design of mobile user interfaces has become a vital part of user satisfaction, ensuring good communication between humans, mobile devices and the services they provide[3, 4]. Designing interface signs that are intuitive for users is crucial for boosting an application's usability[5]. According to ISO 1998, Usability is defined as "*the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use*"[6].

Due to the space limitations of mobile displays, mobile web interfaces frequently use iconic signs to express meaning in a limited display. The challenge of designing effective UIs differs between traditional PCs and for mobile devices due to reasons such as the small size of display screen of mobile devices, different input modalities, and the physical and cognitive limitations of using a system while mobile (e.g. while walking or driving).

In this paper, at the beginning, we identify existing semiotic approaches to the design of UIs. We investigate and criticise the existing models and frameworks that proposed to bridge the gap between designers' intended meaning and users' comprehension through designing and evaluating signs. After that, we justify the certain need to investigate and study semiotics approach to UI within a mobile context. Finally, we discuss and explain the methods required to conduct the first study; followed by an overview of the first study.

2. THEORETICAL BACKGROUND AND MOTIVATION

Semiotics is concerned with answering the different meanings of an element, and thus has relevance to the creation of icons, symbols and signs in HCI. In practical terms in Graphical User Interfaces (GUIs), signs can range from an icon or menu item to a tooltip or animated feature [7]. This section discusses the relevant concepts and background in semiotics and Human-Computer-Interaction (HCI).

A sign is said to consist of three parts: the *object*, the *representamen*, and the *interpretant* [8]. This semiotic triangle is identified by Peirce to explain the relations between these parts. In a sign representation, the thing that the sign refers to is *the object (referent)* .In a UI, an object can be any system's function or program. The representamen is the visible UI element such as buttons, icons or links. The relationship between the object and the representamen can be decoded by the interpretant (user) [7].

Peirce further classified signs into three different categories: icon, index and symbol [8]. The relationship between these parts is a central notion in semiotics. Saussure's [9] model of the sign posits a dyadic relationship- the sign can be represented by a signifier (i.e. an image)- which is the form that a sign takes- and a signified- which is the concept that the signifier represents. In terms of UIs, a design evaluation of various navigational

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elements can benefit from the application of a semiotic method to assess the potential strengths and weaknesses of signs that appear in a UI. For instance, using a floppy disk icon in the design of an application that uses cloud data storage or any different way of storing data is semiotically a weak design as the floppy disk is no longer in use to store data.

Icons are prevalent in many user interfaces. As we have seen above, an icon is one of the three representational forms of signs. It is in fact the simplest form of the three representations of signs as 'it consists of a pattern of lines that physically resembles what it stands for. Icons display features that resemble the object they signify'[10]. In a UI, icons are typically found as an important element of navigation, visually representing an object, idea or action (i.e. a hamburger icon as a visual proxy for a list or menu) [11].

Icons have received extensive examination in semiotic theory. A seminal triadic definition of the icon by Pierce [8], provides an understanding of the issues underpinning its application. The icon can be perceived in relation to its internal qualities (Firstness) that project a resemblance or analogy (i.e. a picture of a computer or person); secondly, it can refer to the entity in terms of its external association or purpose (i.e. a flame denoting fire hazard); and thirdly in relation to how it is interpreted [10]. The second and third components of this definition implicitly support the importance of connecting with the external world and in placing the icon in its external relational context [12].

According to the Piercean model of signs, semiotics involves a dynamic process that is both context-sensitive and interpreter-dependent [13]. For instance, the meaning of two intersecting line 'X', can vary depending on the context. Appearing unaccompanied or embedded in text it can be perceived as the letter "X", however 'X' is also noted to represent malfunction or restriction in some way when embedded within an error message and associated with the colour red. When appearing as a button, it may also imply closing or deleting or removing items [7].

The semiotic approach to UIs acknowledges the contextual basis in the use of icons and can aid in the identification and understanding of the impediments that obstructors are accurately recognising and interpreting the icons. Map icons may be capable of communicating sufficient information to recognise and comprehend navigational or 'map' concepts even with limited contextual familiarity [7]. To accurately perceive the meaning of an icon, often the user needs supportive text labels if that object which represented by the icon is not instantly apparent. This highlights need to account for user needs, and the relationship between cognitive and physical direct design, and use of the icon towards a less ambiguous visual representation [11]. The polysemic nature of icons- an icon indicates to multiple meanings(functions) in a one-to-many relation - implies a subjective dimension that complicates the recognition and understanding of symbols to arrive at an adequate associative conclusion as to the symbol's function [14].

Users interact with web interfaces while perceiving the meaning of signs in the interfaces. In order to interact with interfaces' signs, users are required to interpret / decode the meaning of signs to achieve their tasks through the web interface. According to Derboven et al [15], user's interpretation of interactive systems is primarily focused in HCI by evaluating the user's interpretation to the designer intended meaning. Users interpret the meaning of icons, buttons and other controls to allow meaningful functions provided by an application [15]. The evaluation process of users' interpretations in semiotics remains consistent with the evaluation process in HCI to assess whether the user's interpretation is consistent with the designer intended meaning or not [15].

3. SEMIOTICS METHODS IN HCI

A small number of semiotics frameworks and models have been proposed for designing and evaluating signs in UIs. This section discusses the standards proposed for developing graphical symbols that can be understood by users without supplementary texts, and surveys the semiotic frameworks used in HCI.

ISO 9186 (Public Information Signs) provides a comprehensive methodology to ensure that graphic symbols and signs can easily be recognised and understood by a general audience [16]. In the comprehension test, neither supplementary information nor contextual information with a symbol is shown. Variants of a graphical symbol are presented to participants in a random order. Participants write down their potential interpretations of a variant. Then these interpretations are classified -by three independently working judges- into several categories ranging from *'Correct understanding of the symbol is certain'* to *'No response is given'[17]*.

The reasoning behind this method is to calculate a score for every variant. When scores are calculated, the test decides which variant of a symbol is chosen according to normalized values (100 best, 0 Worst) [16]. When judges do not agree on a specific category, a category assigned by the majority of judges is selected. In order for a symbol to pass the test, at least 67% of the participants surveyed must unequivocally or virtually understand it in relation to its intended purpose, in the absence of supplementary information. This testing would provide a strong indication as to

whether the symbols were designed consistently with expectations of the tested participants. However, as the test takes the majority of judges when they disagree on a specific category, there is a question of reliability. We could take a conservative approach and insist that all the judges agree on a category or the symbol will not be considered. Similarly demandly proposed consistency between different participants' interpretations of a specific variant could make this test reliable, or one might standardise participants' backgrounds to ensure representativeness.

The testing done in this ISO 9186 process is in line with the aim of HCI theory-based evaluation principles in terms of assessing the quality of interfaces and interactions in regard to specific domains such as in public information, pharmaceuticals and road signs [17]. Moreover, it underscored the readability and understanding of pictograms. Pictograms comprehension test have been conducted independently on pictograms presented both within and outside their context. Pictograms represented within their contexts were interpreted more accurately than these represented on their own [17]. Wolff et al recommended that the pictogram should be presented in association with its context (environment) to help reduce the potential polysemy of the pictogram [18].

Semiotics has repeatedly used and studied in the context of HCI. For instance, Semiotics Interface sign Design and Evaluation (SIDE) provides a semiotic framework in order to maximize the usability of UIs. Signs displayed in UIs have been studied and researched through empirical data, and have been modelled at various levels of semiotics theory: syntactic, pragmatic, social, environment and semantics. Primarily, the accuracy of users' interpretations and the level of intuitiveness have been studied and analysed on websites that were studied in the desktop environment. However, none of the context-specific impacts on the accuracy of users' interpretation have been studied or investigated using the SIDE framework [19].

De Souza [20] deconstructs the metacomm-unication process and the messages that describe this interplay. This implies an understanding of who the users are, their needs, preferences and motivations that is supported by the qualitative and interpretative processes posited by semiotic engineering methods. These principles are reflected in the Semiotic Inspection Method [20] that describes five key stages to evaluate the *'communicability of interactive computer-based artifacts'* [21] *including (i) inspection of documentation and help information; (ii) static and (iii) dynamic interface signs; iv) comparison of designer-to-user communications; and (v) conclusive appreciation of overall quality of designer-to-user metacommunication* [20].

The sign concept is central to semiotic inspection. A *signification system* conveys the message from the designer that is conveyed through the significant system. "A signification system is the result of culturally (and, in the special case of HCI, also artificially) encoded associations between contents and expressions" [22]. However, this framework focuses on an *internal* aspect of semiotics analysis in the way to make coherent meaning out of the system elements regardless of the *external* contextual factors (context of use).

Web-Semiotic Interface Design and Evaluation (W-SIDE) [23] is a framework proposed to model and evaluate signs (semiotic unit) in information-intensive web interfaces. Despite its name, W-SIDE is only remotely connected to SIDE, and predates SIDE. W-SIDE has been proposed to bridge the gap in user confusion caused by the pre-supposed knowledge of users when web signs designed and the real knowledge owned by users. Speroni argues that the sign in web interface conveys two layers of meanings: a *content meaning layer* which refers to the prior knowledge of users about the domain of the web UI, and a *functional meaning layer* which refers to the action part of the web interface; when interaction takes place.

In W-SIDE, a set of concepts called an ontology is introduced to support the user knowledge to interpret the meaning of signs in web UIs. One of the ontologies proposed in the W-SIDE framework is the *context ontology* which refers to providing the knowledge of a specific context that a sign appears in. It is limited to the information not explicitly relevant to the website domain but have an implicit relation in making the dialogue possible and comprehensive. In particular, in the *Getty Museum* website, a teachers section has been included to help teachers to reach an educational resource even the topic that the website talks about is *art*.

However, W-SIDE framework doesn't consider the context of interaction or any change of user interaction kind (i.e. driving or walking user).

Semiotics has been used in more novel areas of HCI. Derboven et al [24] investigated users' understanding of a Multi-touch tabletop interface (MuTable) using semiotics. An in-depth analysis of the MuTable Interface was conducted using De Souza's [25] Communicability Evaluation Method (CEM). This analysis started from low-level observations to high-level semiotic profiling in three stages: *(i) tagging* the problems that users encounter with a predefined coding scheme, *(ii)* an *interpretative* stage that involves seeking out the metacommunication problems that appear between the user and the designer and (iii) *semiotics profiling*, an evaluation of how well the designer's message is being transmitted to the user [24].

When users interacted with the MuTable interface, their reaction was categorized using de Souza's communication tags. For example, '*why doesn't* it' is a tag that categorized as *'users seek to clarify the designer's deputy's intended signification'*. This happens when the user wonders about why this part of the interface is not reacting as expected [24]. Since the occurrence of the 'why doesn't it?' tag was extremely high compared with the other two tags 'Oops!' and 'What's this?' tags, three different context-specific situations of 'Why it doesn't it?' tag were analysed. These three context-specific situations are *gesture-context* (when a gesture problem occurs), *navigation-context* (a problem occurs when a user tried to open or navigate between widgets) and *meaning assignment-context* (when the outcome is different than what the user expected). This work created an extension of CEM for multi-touch interaction.

We now turn to examine the domain of mobile usability in general. The implication of the shift from desktop-based computing to mobile devices embedded in all aspects of work and social life has created a focus on frameworks to analyse interactions across a range of mobile contexts [26]. However, this shift implies some limitations and challenges to HCI practice in terms of user perception [27]. *Table 1* shows differences between hand-held mobile devices and desktop-based computing environments according to different properties. Small screen size, display resolution and frequent change of interaction context (driving or walking) might have a significant impact on users' understanding displayed signs.

Table 1: *Differences between mobile- and desktop-based platforms in some properties.*

Environment's Property	**Platform**	
	Mobile-based	***Desktop-based***
SCREEN SIZES	*SMALL*	*LARGE*
DISPLAY RESOLUTION	*2160x3840px (i.e. Sony Xperia Z5 Premium Dual E6833)*	*3840x2160px (i.e. Samsung UD970)*
DISPLAYED INFORMATION	*LESS*	*MORE*
CONTEXT	*POOR*	*RICH*
INTERACTION LOCATION	*MOBILE*	*IMMOBILE*
DISTRACTING OBJECTS	*MORE*	*LESS*
INPUT METHOD	*FINGER SCREEN TOUCHES*	*KEYBOARD/MOUSE*

The constraints of mobile devices have semiotic consequences: because mobile devices have a limited display capability, signs displayed on mobile screens will have a reduced volume to fit the limited display space; and consequently, the amount of information (image/verbal) conveyed by the sign for mobile users will be reduced. Therefore, the users' interpretations may be influenced – often adversely- by the mobile context. On the other hand, having a larger desktop screen size and higher display resolution, signs on a traditional PC are often richly displayed in terms of its volume and the amount of information that conveys to users.

The ability of users to grasp the meaning of icons has already been studied. Tests of users' recognition and comprehension have been conducted on icons of the Official Android 4.0 and the Official iOS 6.1 mobile operating systems [28]. This work investigated the impact of visual form and colour of icons on users' recognisability and comprehension. Designing icons with form and colour can quickly attract user attention and can assist to comprehend the intended meaning [28]. The primary focus of this study is on the visual representation of icons on mobile devices regardless of icons' context. This study showed significant evidence through conducting the comprehension test that many app icons should be improved or replaced in order to improve users' interpretations of the tested icons.

There has been a recent debate on the benefits or weaknesses of *Skeuomorphism*. The concept of *Skeuomorphism* represents an approach that can promote user identification of known objects and potential mechanisms for interaction enhancing the interface learnability [7]. *Skeuomorphism* occurs when images are based on real images that are manipulated by design features, such as depth, or lighting, to represent a familiar real-world object such as a clock. The imitation of objects and interactions is thought to facilitate user identification by providing straightforward and generalised cues that represent complex meanings [7].

In contrast, a *flat design* embodies a minimalistic approach emphasising reduced but focused information and interface design targeting the critical elements [7]. In contrast to *Skeuomorphism*, rather than real-world objects, the emphasis is often on iconic or abstract symbols, streamlined, decluttered, 2D shapes and contrasting colours. This is argued to support the commitment to the design usability through focusing on the message and content [7]. However, Stickel et al. identified a risk of losing meaningful information due to design simplification. Icons that employed strong, meaningful shapes were found to be more effective. The key lesson in the use of flat design is to ensure semantic precision and focus in the use of icons to maximise usability [7].

For a user who is sitting down and interacting with a website on a desktop, a large volume of the user's cognitive resource is demanded to recognise and interpret icons due to the absence of distracting objects. In contrast, when users are

walking or driving while interacting with a website on a mobile device, this allows the surrounded objects to pressure the cognitive resource of users (i.e. walking and interacting with Google Maps on an iPhone).

To help analyse the cognitive load of users in a mobile context, Oulasvirta [26] introduces the notion of "cognitive resource competition" based on the assumption that the multitasking nature of mobile computing creates competing pressure for finite cognitive resources. It examines social, interactional and psychological processes in mobile computing and maps them to cognitive resources. Oulasvirta argues that the framework can assist in isolating users' perceptual, attentional, and cognitive capabilities in mobile contexts. This implicates a novel perspective on user contexts and the potential consequences for users' interpretative and attentive capacity. This perspective points to design implications for UIs to consider deeper psychological elements.

The role of semiotics on UIs as a method grounded in theoretical concepts provides guiding principles and concepts that enable deeper insights into the improvement of user's interpretation of signs through design. Also, identifying the relation between users' interpretation in semiotics and the cognitive and psychological impacts on that; manifest a unique communication between users and designers in HCI.

In conclusion, many evaluation methods have been employed to improve usability such as usability evaluation in the web development process [29]. Semiotic analysis is one of the methods that has been considered for improving usability of UIs and usability evaluation in *desktop-based* computing platforms; but not in mobile devices.

4. AIM AND SCOPE OF THE STUDY

This study aims to address the following research question: *What is the impact of the sequence of interaction as a contextual factor on users' interpretations of UI's signs on a mobile device?*

UIs are designed with many signs as a means of conveying the meaning of interface signs for users. Due to the common use and intentional nature of web interfaces, the study will be conducted in the context of web interfaces on mobile devices. The intentional nature of signs means that a designer created a sign in order to deliver a meaning (function) for users [30]. We take the interpretations of the meaning of signs on a custom-designed holiday booking website.

We intentionally controlled the context that signs appear in to alter their potential interpretations. There are many mobile contextual factors needing investigation as they may have significant impacts on user's interpretation of signs in UIs such as:

- The context of a UI's structure in a website or an app. Organizing and presenting relative signs to be next to each other (neighbours) and contrasting unrelated signs from each other. The context of UI's structure could impact users' interpretation via intergroup saliency [31].
- User context (users vary) in interacting with a website or an app will vary between users due to different goals or knowledge. The impact of variations of sequential interactions is one example that might influence user comprehension and interpretation of intentional signs.
- The physical location where a user interacts with a website or an app is part of the context of use[32]. The physical location of interaction could influence the cognitive resource of users who are interpreting signs that appear in an app. For instance, in a tour guide website, a user interacts with and understands specific signs related to the nearby point of interest according to the current location.
- Mobile devices have limited screen sizes. Consequently, the design of the website or the app has to adapt to fit the available space. Also, users commonly use one hand to communicate with the device. Therefore, signs- as a website or an app design factor- on mobile devices need to be well-designed to maintain effectiveness and efficiency of use [33].

As we discussed above the sequence of interaction context (context of use) is part of the overall context of a website interaction. We chose to investigate the sequence of interaction in our main study as it had discernibly altered user's interpretations of signs in our pilot study. Interacting with a website in a specific sequence (i.e. web page (A) followed by web page (B)) often varies from one user to another. Eliciting the impact on users' interpretation of a sign through different sequences is targeted to relatively and effectively improve the design in the next study. The primary focus of this study is placed on the effect of the sequence of interaction through a website on users' interpretation. The study will be conducted using *an iPhone 5s*; where the official recent *Apple iOS* mobile operating system, and the *Google Chrome* browser are installed. For the purpose of this study, the various sequences of interaction will be investigated in stationary places (i.e. interacting while sitting on a desk).

5. DESIGN AND METHODS OF THE INITIAL STUDY

This study focuses on showing that participants' interpretations of icons can change when the sequence of interaction changes, particularly in the case of mobile systems. A comparative study will be conducted to trace changes among two groups of users through *summative assessment* after the

initial *formative* part since the website has been designed and developed [34, 35]. Each group will be taken independently through a specific sequence of interaction to compare potential changes in participants' interpretations. The main purpose of summative assessment is to proportionally evaluate the impact of the sequence of interaction on the accuracy of participants' interpretations to be either *effective* (it alters the interpretations of a high number of participants) or *ineffective*; (it didn't alter, or it alters the interpretations of few participants). Having an effective contextual factor will guide us to the next study that will focus on improving the accuracy of users' interpretations within varied interaction sequences.

Summative assessment helps in identifying the change of participant's behavior in early stages of the research. Therefore, this will lead the research to identify an effective contextual factor on participants' interpretation and tackle the *causes* for this participant's interpretation to change; which represents the *formative* part of the study. Formative assessment [34, 36] in the study will help to improve participants' interpretations through design guidance (recommendation) which represents the knowledge that this research is contributing; and aiming for *consistent* and *preferred* design state through semiotics perception.

The roles of these two activities in the research study will show how much they overlap or are complementary to each other. For instance, without understanding and identifying the significance of the change in participant interpretations, a design researcher will not be able to identify the causes of such a change, and this will lead to difficulties in suggesting improvements. These two assessment activities will be conducted on every iteration process through a design research approach.

This study is consolidated to define the change in participants' interpretations based on two distinct sequences of interaction. It will prove/disprove that the sequence of interaction is an effective mobile contextual factor on participants' interpretation. Having a key contextual factor, in the next study, the formative assessment will be conducted to suggest semiotics guidelines that aim to improve the accuracy of participants' interpretations.

The interview occurs throughout the study as the participant encounters selected signs. During the interview, the interviewer and the participants will discuss interpretations of the selected signs and enable the exposure of a participant's perception. Therefore, semi-structured interviews are used to conduct a summative assessment of the accuracy of participants' interpretation in identifying the change. Participants will be interviewed to interpret the meaning of UI signs in two different stages pre-interaction and post-interaction. The change in participants' interpretation of a sign during these stages proves participants' confusion of that ambiguous sign. Having no change between participants' interpretations means the tested sign clearly represents its purpose in the UI and is considered meaningful for users. This study also investigates to what extent users refer to the sign and its context in their comprehension.

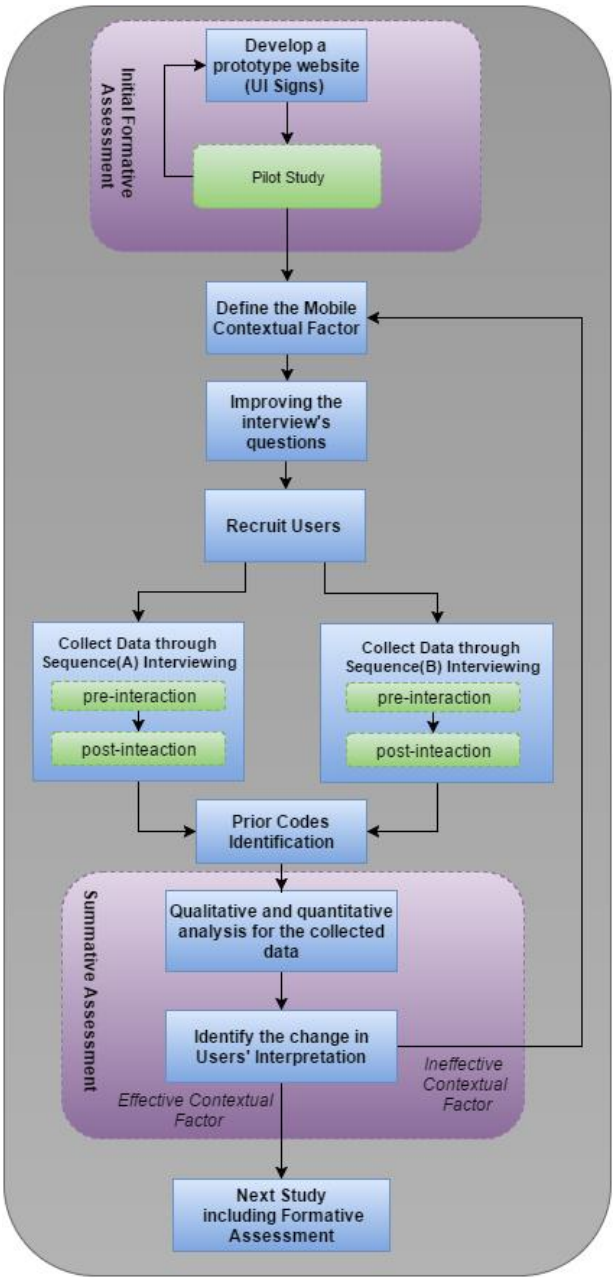

Figure 1: An overview of the initial study

Figure 1 illustrates the required methods that will be conducted for each process. The primary focus of this study concerns the summative activity to evaluate the effectiveness of the sequential interaction as a contextual factor. It also includes processes preliminarily conducted for investigating the research problem such as the pilot study.

Priori codes will be identified to categorize the accuracy of participants' interpretations according to the designer's intended meaning of icons. Hence, a participant interpretation of an icon can be categorized as '*Accurate'*; when that interpretation is matching the designer's intended meaning of that particular icon. Also, while analyzing the collected data; concrete codes will be concluded from the data to identify the causes for the participants to change their interpretations throughout different sequential interactions. Hence, '*last experience', 'last experiment' or 'previous page'*; when participants recall the recent experience they had in a particular webpage of the sequence to interpret the meaning of an icon.

After conducting qualitative analysis on the collected data, quantitative analysis will be conducted to show how effective is the sequential interaction as a contextual factor on participants' interpretations.

6. SIGNIFICANCE OF THE STUDY

As we have discussed, employing semiotic methods on mobile web interfaces and mobile applications remains under-researched. Considering the mobile context while interacting with websites and apps implies design challenges for responding to the context of use, and in particular enhancing the accuracy of users' interpretations of signs. Therefore, the application of semiotics perception to mobile web interfaces is a topic that merits further investigation. This research particularly focuses on the role of context-specific semiotics to improve mobile usability.

Moreover, the context of signs may be more important on mobile devices than on traditional PCs, due to the lack of screen size, and, therefore, a reduced volume of supportive information that can be displayed.

When users are mobile, the context of use changes frequently. Thus a user's goals and understanding will also change. A mobile context comes from multiple facets such as: the interaction location where the user interacts with the mobile device [32]; time of day and recently user apps or websites. To get the best out of a mobile context in terms of user's comprehension and interpretation, we need to respond in context and combine their facets effectively. Mobile users can be supported by combined contextual resources to accurately interpret the meaning of signs that are being used. Moreover, users interpret signs according to the way they navigate within a website or an app.

The original contribution of this research is to study the impact of different contextual factors (i.e. interaction sequences) on how users interpret signs in the context of a mobile phone. For instance, in a holiday booking website that has two main UIs (hotels and flight interfaces), users can use the website via different navigation sequences.

Semiotic design principles and guidelines have been proposed in SIDE[19] to improve the usability of UIs on traditional desktop-based platforms. However, our research will uniquely form effective design principles and guidelines for UI practitioners on the role of semiotics to enrich the sequential interactions as a contextual factor. Enriching the mobile context through the sequential interactions will improve the accuracy of users' interpretations. Therefore, this will contribute an understanding of the role of context within semiotics methods in maximising usability of web interfaces on mobile devices. Studying the impact of the specific sequential context that signs appear in on the subsequent interpretation of the signs will help in identifying the scale and nature of the effect.

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