Muhammad Nazrul Islam

Design and Evaluation of Web Interface Signs to Improve Web Usability

A Semiotic Framework

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Muhammad Nazrul Islam

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To my parents and to my family

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Turku, Finland — Muhammad Nazrul Islam
October, 2014

Abstract

Technological innovations, the development of the internet, and globalization have increased the number and complexity of web applications. As a result, keeping web user interfaces understandable and usable (in terms of ease-of-use, effectiveness, and satisfaction) is a challenge. As part of this, designing user-intuitive *interface signs* (i.e., the small elements of web user interface, e.g., navigational link, command buttons, icons, small images, thumbnails, etc.) is an issue for designers. Interface signs are key elements of web user interfaces because 'interface signs' act as a communication artefact to convey web content and system functionality, and because users interact with systems by means of interface signs. In the light of the above, applying semiotic (i.e., the study of signs) concepts on web interface signs will contribute to discover new and important perspectives on web user interface design and evaluation.

The thesis mainly focuses on web interface signs and uses the theory of semiotic as a background theory. The underlying aim of this thesis is to provide valuable insights to design and evaluate web user interfaces from a semiotic perspective in order to improve overall web usability. The fundamental research question is formulated as *What do practitioners and researchers need to be aware of from a semiotic perspective when designing or evaluating web user interfaces to improve web usability?*

From a methodological perspective, the thesis follows a design science research (DSR) approach. A systematic literature review and six empirical studies are carried out in this thesis. The empirical studies are carried out with a total of 74 participants in Finland. The steps of a design science research process are followed while the studies were designed and conducted; that includes (a) problem identification and motivation, (b) definition of objectives of a solution, (c) design and development, (d) demonstration, (e) evaluation, and (f) communication. The data is collected using observations in a usability testing lab, by analytical (expert) inspection, with questionnaires, and in structured and semi-structured interviews. User behaviour analysis, qualitative analysis and statistics are used to analyze the study data.

The results are summarized as follows and have lead to the following contributions. Firstly, the results present the current status of semiotic research in UI design and evaluation and highlight the importance of considering semiotic concepts in UI design and evaluation. Secondly, the thesis explores interface sign ontologies (i.e., sets of concepts and skills that a user should know to interpret the meaning of interface signs) by providing a set of ontologies used to interpret the meaning of interface signs, and by providing a set of features related to ontology mapping in interpreting the meaning of interface signs. Thirdly, the thesis explores the value of integrating semiotic concepts in usability testing. Fourthly, the thesis proposes a semiotic framework (Semiotic

Interface sign Design and Evaluation – SIDE) for interface sign design and evaluation in order to make them intuitive for end users and to improve web usability. The SIDE framework includes a set of determinants and attributes of user-intuitive interface signs, and a set of semiotic heuristics to design and evaluate interface signs. Finally, the thesis assesses (a) the quality of the SIDE framework in terms of performance metrics (e.g., thoroughness, validity, effectiveness, reliability, etc.) and (b) the contributions of the SIDE framework from the evaluators' perspective.

Sammanfattning

Teknologiska innovationer, utvecklingen av internet och globaliseringen har ökat informationssystemens komplexitet och antalet webbapplikationer. Därför är det en utmaning att säkerställa att användargränssnitten på webben är förståeliga och användbara (med tanke på användbarhet, effektivitet, och tillfredställelse). Detta innebär att designen av intuitiva tecken (d.v.s., de elementära komponenterna i ett användargränssnitt, t.ex. länkar, knappar, ikoner osv…) för webbens användargränssnitt blir en utmaning för webbdesigners. Då användare arbetar med interaktiva system på webben, är användargränssnittens tecken och symboler nyckelkomponenter, eftersom de fungerar som kommunikationsmedel för innehåll och funktionalitet. En användning av semiotik (studiet av tecken) för att skapa användargränssnittets tecken ger nya och betydelsefulla perspektiv på design och utvärdering av användargränssnitt.

Denna avhandling fokuserar främst på användargränssnittets tecken och tillämpar semiotiska teorier på detta område. Syftet med avhandlingen är att forma nya insikter om design och utvärdering av webbens användargränssnitt för att förbättra användbarheten på webben. Avhandlingens centrala forskningsfråga är – *vad behöver designers och forskare känna till om semiotik för att förbättra användbarheten när de skapar eller utvärderar användargränssnittet för webbsidor*?

I avhandlingen används en "design science"-forskningsansats. En systematisk litteraturöversikt och sex empiriska studier har genomförts. De empiriska studierna bygger på ett totalt urval av 74 testpersoner. "Design science"-forskningsprocessen har tillämpats på följande sätt: a) identifiering och motivering av forskningsproblemet; b) definition av målsättningarna för en problemlösning; c) design och utveckling av en lösning; d) demonstration av en fungerande lösning; e) utvärdering och f) presentation av forskningsprocessens resultat. Det empiriska underlaget har samlats in med observationer under kontrollerade laboratorieexperiment, genom analytiska utvärderingar, enkäter och strukturerade och halvstrukturerade intervjuer. Analyser av användarbeteende, och kvalitativ och statistisk analys har också använts.

Resultaten sammanställs på följande sätt och redovisar följande forskningsbidrag. Nuvarande kunnande om användning av semiotik inom design och utvärdering av användargränssnitt presenteras; denna inventering visar hur viktigt semiotiken är inom detta område. I avhandlingen undersöks och identifieras ett antal ontologier för användargränssnittets tecken (d.v.s., de begrepp och färdigheter som användaren ska behärska som en förutsättning för att tolka ett teckens betydelse). Nyttan av att inkludera semiotiska begrepp som

en del av testningar av användbarhet undersöks. Ett ramverk med semiotisk underbyggnad (Semiotic Interface sign Design and Evaluation – SIDE) för design och utvärdering av användargränssnittets tecken har utvecklats; SIDE-ramverket innehåller en mängd faktorer och attribut för att användargränssnittets tecken skall vara intuitiva för användaren, samt riktlinjer för design och utvärdering av dessa tecken. Ramverkets bidrag till testningen av användbarhet valideras med stöd av olika indikatorer för prestanda, bl.a. utförlighet, validitet, effektivitet och tillförlitlighet. Slutligen har också olika metoder utvecklats för att använda semiotiska verktyg inom design och utvärdering av användargränssnitt.

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Paper II: Islam, M.N., & Tétard, F. (2014). Exploring the Impact of Interface Signs' Interpretation Accuracy, Design, and Evaluation on Web Usability: A Semiotics Perspective. *Journal of Systems and Information Technology*, Vol. 16 (4), Emerald publishers.

Paper III: Islam, M. N. (2012). Semiotics Perception towards Designing Users' Intuitive Web User Interface: A Study on Interface Signs. In H. Rahman, A. Mesquita, I. Ramos, and B. Pernici (Eds.), *Proceedings of the 7th Mediterranean Conference on Information Systems*, Lecture Notes in Business Information Processing , LNBIP Vol. 129, pp. 139-155, Springer-Verlag.

Paper IV: Islam, M. N. (2013). Towards Determinants of Designing User-Intuitive Web Interface Signs to Improve Web Usability. In M. Aaron (eds.), *Proceeding of the 15th International Conference on Human-Computer Interaction (HCI International 2013)*, Lecture Notes in Computer Science, LNCS Vol. 8012, pp. 84-93, Springer-Verlag.

Paper V: Islam, M.N., & Tétard, F. (2013). Integrating Semiotics Perception in Usability Testing to Improve Usability Evaluation. In M. Garcia-Ruiz (Eds.) *Cases on Usability Engineering: Design and Development of Digital Products*, pp. 145-169, USA: IGI Global.

Paper VI: Islam, M.N. (2014). Towards User-Intuitive Web Interface Sign Design and Evaluation: A Semiotic Framework. (*Submitted to International Journal of Human-Computer Studies*)

Paper VII: Islam, M. N., & Bouwman, H. (2014). An Assessment of the Semiotic Interface sign Design and Evaluation (SIDE) Framework. In *Turku Centre for Computer Science (TUCS) Technical Report*, TR No - 1106, ISBN: 978-952-12-3048-6, April, 2014.

The contribution of the author to the original publications

Paper I: Single author.

Paper II: Main author. Design the tests with the co-author. Conducted the tests and analyse the data. Wrote most of the paper.

Paper III: Single author.

Paper IV: Single author.

Paper V: Main author. Design the tests with the co-author. Conducted the tests and analysed the data of first two tests. Analysed study data of third test with co-author. Wrote most of the paper.

Paper VI: Single author.

Paper VII: Main author. Design and conduct the tests. Analyze the data with the co-author. Wrote most of the paper.

Part I:

Overview of the Dissertation

Chapter 1

Introduction

This chapter presents the starting points of this research. First, the background of the research is introduced. Then the motivation and the research problems are discussed. Next the research objectives and questions are presented. After that the outline of the research process and the linkages between the original publications and the research questions are presented. Then the scope of the research is discussed. Finally, the structure of the dissertation is presented.

1.1 Research Background

The World Wide Web is one of the premier applications of the global internet. Nowadays, the web takes a crucial part in internet marketing, online business, entertainment, education, information communication, and collaborative work. In order to achieve this wide range of application areas of the web, the web needs to be used in different ways and in different contexts by a wide range of users. This means that designing well-fitted and uniform web user interfaces for a wide range of users is a complex task (Benito, 2011). Moreover, over the past decades with the advent of globalization and the rise of information and communication technologies, the number and the complexity of web applications and interfaces have increased to keep the web interfaces understandable and usable. As a result, well-designed web user interfaces (UI) are essential to reach the goals of designers and end users.

This research is grounded in four general research fields. These are: human-computer interaction, web UI design, usability engineering, and semiotic. These foundations are introduced in the following paragraphs. The foundations offer prospects for not only validating and extending earlier results, but also for studying new and innovative aspects in the field of web UI design and evaluation through a semiotic perspective.

Until the 1980s, the software development process was primarily technology-oriented, thus focused mainly on system functionality and reliability. A key issue

for software developers has emerged in the last few decades mainly due to the commercialization and competition in the global software market: this issue includes making the software more easy to use. Ease-of-use of a software product implies that software developers' focus should shift from systems functionality and reliability to users' pleasure, joy, understandability, easiness, learnability, and satisfaction. Ease-of-use of information systems has gained ground, and the field of Human-Computer Interaction (HCI) addresses the issue of ease-of-use of information systems.

HCI is an interdisciplinary field that is mainly concerned with the study, design, evaluation, development as well as implementation of human-centric interactive information systems. The ACM special interest group of CHI defines HCI as "a discipline concerned with the design, evaluation, and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them" (ACM SIGCHI, 1992). Tufte (1989) defines HCI as "HCI can be viewed as two powerful information processors (human and computer) attempting to communicate with each other via a narrow-bandwidth, highly constrained interface" (Tufte, 1989). In fact, HCI studies how a computer system is designed more practically, more easily, and more intuitively; and it also studies how users interact with such computer systems (Fetaji et al., 2007). Users' interactions with a computer system have an explicit emphasis on the 'interaction at the interface' (Fetaji et al., 2007). Due to the basic features of web user interfaces (e.g., with a click of the mouse, a web interface allows one to navigate a link across the world), the web has become interactive. Thus, the web is considered to be a direct result of HCI research (Myers, 1998), and developing well-designed web user interfaces is a significant concern in order to make an effective HCI.

The web offers a rich environment for the presentation of information through its interfaces. A well-designed web user interface is made with a focus on end-users, and acts as an effective interaction or presentation tool to allow end-users to obtain the information they are looking for (Dix et al. 1998). Thus, a well-designed web user interface always offers a satisfactory user experience, and usability is considered to be a key quality attribute of a well-designed web UI.

Usability measures ease-of-use of a system and addresses the aspects of user experience (e.g., users' experiences will be better when the usability of a system is better). 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" (ISO 9241-11 1998).

Usability evaluation is the process during which practitioners test, verify, and validate the results of the design process. Thus, usability evaluation methods (UEM) are considered an important quality (i.e., usability) assessment technique

to evaluate web user interfaces. A number of UEM have emerged and evolved in the field of usability (Whitefield et al., 1991; Insfran & Fernandez, 2008). For example, (i) task analysis (evaluation driven by analysis of users' tasks) (Diaper & Stanton, 2003), (ii) heuristic evaluation (examination of user interfaces based on recognized usability principles or heuristics) (Nielsen, 1999; Nielsen 1994; Nielsen & Molich, 1990), (iii) cognitive walkthrough (a task-specific cognitive inspection method) (Hertzman & Jacobsen, 2003), (iv) think-aloud (evaluation of the usability of a system by encouraging participants to think aloud while they are performing system-related tasks) (Hertzman & Jacobsen, 2003; Nielsen, 1993), (v) questionnaires (Nielsen, 1993), and (vi) interviews (Nielsen, 1993).

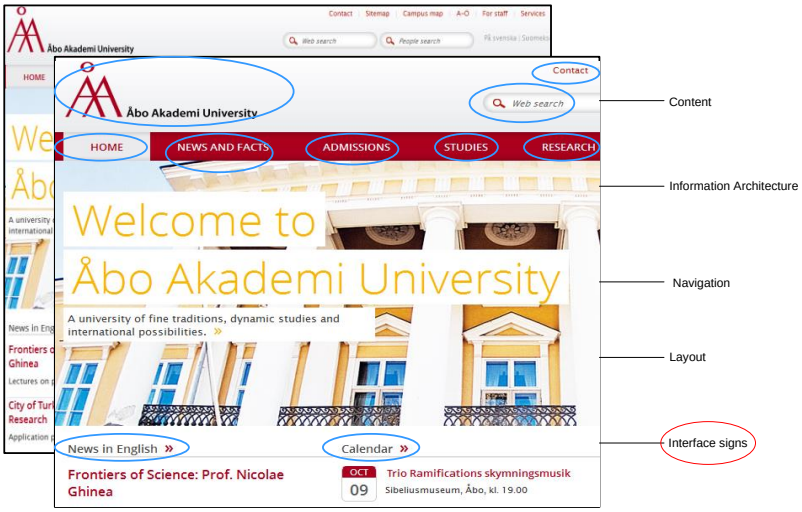


Figure 1. Snapshot of Åbo Akademi homepage shows (i) some interface signs marked by ovals, and (ii) user interface design and usability evaluation dimension (retrieved from www.abo.fi in October, 2013)

Every interactive application, especially navigational tools or web pages, necessarily incorporates a large extent of navigational links, labels, icons, symbols, short texts, thumbnails, command buttons, images, etc. (Neumuller, 2001). These elements of web user interfaces are called in this thesis 'interface signs' (see figure 1). According to Peirce(1931- 58), each sign should have its own triadic relation, that consists of (a) the *representamen* corresponding to the representation or form of a sign, (b) the *object* corresponding to the referential meaning or underlying functionality, and (c) the *interpretant* corresponding to the meaning (or a sign) generated in the mind of the interpreter or user. So, the key features of considering anything as a sign are: (i) it should have some meaning or stand for something else, and (ii) it should be interpreted by someone. Based on this definition, a whole website (e.g., an e-commerce website) can be considered as a sign since a website as whole can convey

messages to its users; and a particular webpage (e.g., a product list of an e-commerce website) can also be a sign since a webpage as a whole can provide messages to the users. Similarly, small elements of a web page (e.g., a navigational link or label of product item of a product-list page of an e-commerce website) can be considered as signs since these elements convey meaning or functionality to the users. In this thesis, we focus on the small elements of user interfaces that are defined as interface signs. For example (see figure 1), the small element 'Calender >>' at homepage of Åbo Akademi's website refers to a unique meaning or functional message (i.e., shows the events of ÅA according to the calendar dates) to users; thus 'calender>>' can be considered as an interface sign. In this thesis, the interface sign can be a single sign like 'contact', 'home', 'admissions'; or with an appended icon/symbol/short texts that are strongly interrelated and composing a unique meaningful and functional message like 'News in English >>', 'web search with the search icon', 'logo of åbo akademi with the text åbo akademi university'. These interface signs act as communication artefacts in web UI to convey information about web content and system functionality. End-users interact with user interfaces through interface signs, which make them crucial elements of web user interfaces. Designers should design interface signs to be intuitive for end-users, so that end-users can understand the referential meaning of interface signs accurately and perform their desired tasks properly. The principles of designing interface signs focus on sense production and interpretation, and thereby involve *semiotics* - the science or doctrine of signs (Peirce, 1931- 58). Thus, semiotic aspects are required to construct well-designed web user interfaces, which in turn support better web usability. Achieving a better usability standard is one of the basic arguments of effective HCI. Therefore, the association among the fields of research could be presented by the following expression:

$$(Semiotic \xrightarrow{required\ for} UI\ design \& evaluation) \xrightarrow{to\ achieve} Usability \in HCI$$

In summary, this research applies semiotic concepts to investigate issues related to the design and evaluation of 'interface signs' (i.e., the small elements of web user interface) in order to improve the overall system usability. Thus, the research contributes to the fields of semiotic, HCI, UI design and usability evaluation in general. The motivation and research problems are discussed in the following section.

1.2 Motivation and Research Problems

Interface signs are the key elements of web user interfaces because users interact with systems by means of interface signs; and because interface signs act as

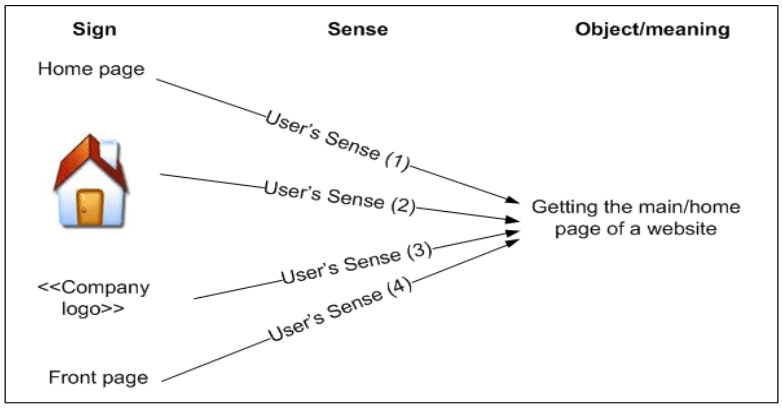
communication artefacts between the users and systems or designers (Bolchini et al. 2009; Speroni, 2006; De Souza, 2005a).

Interface signs are also considered to be one of the most complex elements of web user interfaces since an interface sign is designed by encoding a referential meaning or object(s), and a user should correctly decode this sign to understand the accurate meaning of the sign. But the relationship between an interface sign and its meaning (or referential object) is not always an exclusive one-to-one relationship. A few cases of this relationship and the observable facts related to each case are presented below:

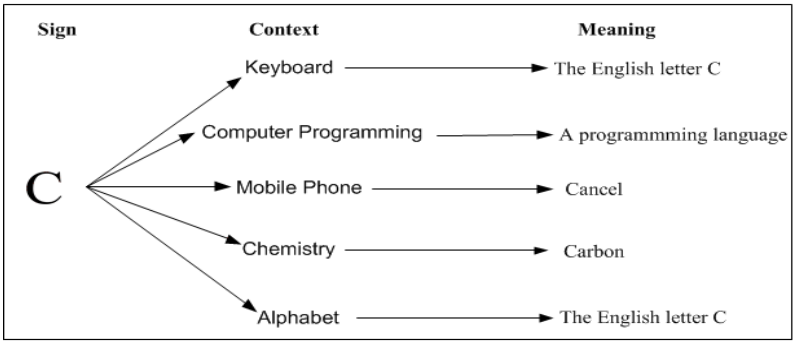
a) Multiple signs may refer to one meaning or object in spite of referring to several meanings (Frege, 1879). Each sign has its own sense that leads different users to understand the same meaning. For example (see figure 2.a), four different signs of a homepage may refer to the same object or meaning (i.e., 'Getting the main/home page of a website') by different interpreters. But the fact is, designers cannot choose multiple interface signs to express a single meaning or object in a web interface. Moreover, a user might not be able to interpret the meaning of every sign accurately, i.e., a sign may be more intuitive than others.

b) A sign may refer to multiple meanings depending on the context of the sign (Eco, 1976). For example (see figure 2.b), the meaning of the sign 'C' varies depending on the context of the sign. If a sign *S* refers to the meaning *M* in the context *C* then designers should appropriately create the context C for S (sign) to understand M (meaning) while designing the user interface.

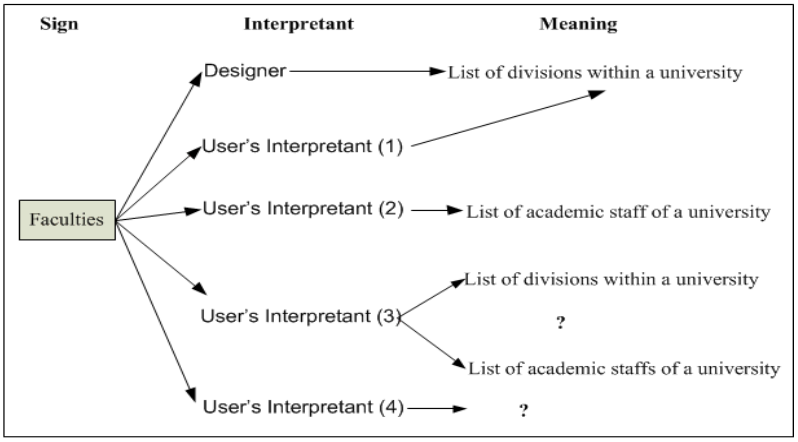
c) A sign's meaning can be interpreted in multiple ways by different interpreters (or users). For instance, a user can accurately interpret the meaning of an interface sign as the meaning assigned by the designer, or as a different meaning other than the designer's assigned meaning; or a user may be confused when interpreting the meaning of a sign, or a user may not understand the sign at all. Figure 2.c shows how the 'Faculties' sign in a university website can be interpreted in several ways by different users. Some questions arise from this example: why and how do users interpret the meaning of interface signs accurately? why are some users not able to interpret the meaning of interface signs properly? why do some users completely fail to understand the sign? and how can UI practitioners select or design the most appropriate sign (i.e., the most intuitive interface sign) for end-users so that they can interpret the meaning of an interface sign easily and accurately?



(a)



(b)



(c)

Figure 2. Possible interpretation of interface sign(s)

Therefore, designers should consider a number of factors related to (i) interface sign and its meaning, (ii) the context of the sign, and (iii) users' presupposed knowledge to interpret the meaning of the sign, in order to design user-intuitive interface signs. As a result, a number of questions are posed, such as: what factors are associated to the interpretation of the meaning of interface signs, what kind of presupposed knowledge users own for interpreting signs; what factors make a sign intuitive for users; and what increases the users difficulty in interpreting the meaning of an interface sign. Thus, making interface signs intuitive for users in order to improve web usability and achieve better user experience is a big challenge for UI practitioners.

The design and usability evaluation of web user interfaces generally address five dimensions that includes content, information architecture, navigation, layout, and interface signs (Bolchini et al. 2009) (see figure 1). If two web applications are identical concerning the content, information, navigation and graphic/layout but only differ in terms of interface signs, then we propose that the application including more intuitive interface signs will show a better usability standard. In other words, accurate interpretation of interface signs has an impact on system usability. A significant number of studies has been carried out (e.g., Eichinger & Schrefl, 2009; Takagi et al., 2007; Nebeling et al., 2011; Sutcliffe, 2002; Granic et al, 2008), that mainly focus on every other aspect of web interface design and evaluation (i.e., graphics or layout, navigation, content, and information architecture), but surprisingly web interface signs have always been neglected (Speroni, 2006; Speroni et al., 2006). As a result, the aforementioned critical observations related to the relationship between an interface sign and the meaning of this sign are still not empirically investigated and resolved. Therefore, UI practitioners still lack concepts to design and evaluate user-intuitive interface signs.

A number of usability evaluation methods have been proposed during the last few decades (Insfran and Frenandez, 2008). Only a few methods have considered semiotic issues to evaluate the usability of web applications, since most of them do not explicitly analyze the intuitiveness of interface signs. Some well-structured usability evaluation methods consider semiotic aspects as generic criteria to evaluate the usability of web applications, but these are often confusing and blended with other usability aspects (e.g., layout design, aspects related to content, etc.) (Triacca et al., 2003). That means that very few evaluation methods give the right importance to semiotic aspects for interface design and evaluation in order to improve system usability.

Moreover, during the last two decades, a limited number of studies that yielded semiotic in HCI have been carried out. For example, to allow the analysis of intrinsic values of interface signs, a few approaches have been developed including: (a) the web-semiotic interface design evaluation (W-SIDE)

framework to evaluate information intensive web user interfaces (Speroni, 2006); (b) the semiotic inspection method (SIM) for interface evaluation grounded in the theory of semiotic engineering (De Souza, 2005a, De Souza *et al*., 2006); (c) the Milano-Lugano evaluation method (MiLE+) that applies semiotic aspects to analyze the application-independent features of web user interfaces (Triacca *et al.*, 2005; Bolchini and Garzotto, 2007); (d) the shared meaning design framework (SMDF) to improve the overall HCI performance (meaning, complexity, and usability) in e-commerce applications (French et al., 1999).

However, a systematic literature review was carried out to investigate the current status of semiotic research in UI design and evaluation. The review results are discussed in chapter 4 (section 4.1) and published in *Paper I*. The review outlined further research opportunities as a response to identified research gaps, such as developing more complete and generalized guidelines and frameworks for UI design and evaluation, considering semiotic aspects in usability evaluation, and giving more attention to the validation of the semiotic frameworks and guidelines for interface design and evaluation.

These aspects highlight the need to include semiotic concepts in web interface design and evaluation in order to make interface signs intuitive for end-users and to improve web usability. Here, the concept of user-intuitive interface sign refers to an interface sign that makes it easy and intuitive for end-users to accurately understand or interpret its referential meaning. An intuitive interface sign reflects its actual content or meaning in order to better meet the needs of user; so that users are driven directly towards the actual content they are looking for. Users do not need to click on an interface sign to see the referential content or function to understand the meaning of the sign in question. In HCI, such intuitiveness is an explicit goal in order to improve usability as well as to achieve better user experience, since interpretation is central to HCI and, at a low level, users interpret interface signs (e.g., icons, buttons, other controls) to understand the system's functionality and to interact with the system (Derboven et al., 2013).

To sum up, the above discussion makes clear that semiotic has a significant role in HCI and also highlights the need for further research that will support the design and evaluation of user-intuitive interface signs to improve web usability. The thesis is carried out with a focus on web interface signs aiming at investigating and resolving a number of issues on the design and evaluation of user-intuitive interface signs, and aiming at filling the research gaps to some extent. The research objectives, questions and scope are discussed in the following section.

1.3 Research Objectives and Questions

The underlying goal for the UI practitioners (interface designers and usability evaluators) is to create web interface signs whose meaning would be easy for end users to interpret properly.

The thesis focuses on web interface signs and investigates a number of issues from a semiotic perceptive; that includes: why user-intuitive interface signs are important to improve usability of a system; why some signs are intuitive to users whereas other signs are not; which associated factors affect users to interpret the meaning of interface signs easily and accurately; what kind of users' presupposed knowledge is needed to interpret the meaning of interface signs, and how semiotic can improve the intuitiveness of interface signs and the usability of a system.

The main objective of this thesis is to provide valuable insights with which to design and evaluate web user interfaces in order to improve system usability from a semiotic perspective. Another objective of this thesis is to move the field of semiotic research in UI design and evaluation a step forward, and to propose HCI researchers that the development and state of semiotic research is practical and useful for UI design and evaluation.

Based on the background theory and the research problem stated before, the overall research question to be explored is: *What do practitioners and researchers need to be aware of from a semiotic perspective when designing or evaluating web user interfaces to improve web usability?*

Detailing the fundamental research question, there are five research questions that can be derived and are relevant for web user interface design and evaluation:

- *RQ1*: What kinds of semiotic research have been employed in UI design and evaluation, and how are they employed?

- *RQ2*: Why is considering semiotic concept in user interface design and evaluation so important to improve web usability?

- *RQ3*: What benefits are observed by integrating the semiotic concept into usability testing?

- *RQ4*: What semiotic instruments are needed to design user-intuitive web user interfaces to improve web usability?

- *RQ5*: How applicable are the proposed semiotic instruments to design and evaluate web user interfaces?

1.4 Outline of the Study and the Linkages of the Publications with the Research Questions

From a methodological perspective, the research follows a design science research (DSR) approach. The research is carried out following the steps of the DSR process (Peffers et al. 2007); that includes: problem identification and motivation, definition of objectives of a solution, design and development, demonstration, evaluation, and communication. Each step is discussed comprehensively in chapter 3. Here an outline of the research process is provided, that builds on the three main phases that incorporated the six steps of the DSR process. For the sake of readability and clarity, the research process is presented here as a linear set of phases, though the actual research is carried out iteratively. Figure 3 shows an overview of the research process.

The first phase is dedicated to understanding the state-of-the-art concerning studies of semiotic in user interface design and evaluation; as well as the characteristics, gaps and limitations of this domain. A systematic literature review is carried out following Kitchenham's (2004) systematic literature review approach. In addition to understanding the strengths, gaps, and challenges of semiotic research in UI design and evaluation, the review results effectively contribute to direct the rest of the phases of this research. The outcome of this phase gives answers to research question *RQ1*.

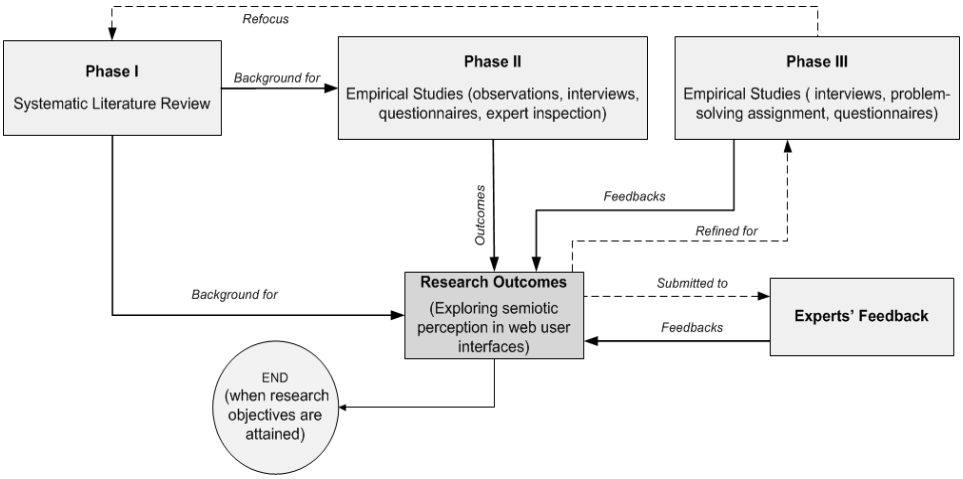


Figure 3. An overview of the research method

The second phase is commenced by five empirical studies. Four out of five empirical studies are conducted on web user interfaces through user tests, and replicated with a total of 51 participants in Finland. Another study is carried out through an analytical (expert) inspection followed by a lightweight focus group

discussion, and investigates a total of 404 web interface signs. The outcome of this phase gives answers to research questions *RQ2 – RQ4* and partly to research question *RQ5*; for example, formulation of a set of semiotic features for user-intuitive interface sign design and evaluation, and construction of a semiotic framework for interface sign design and evaluation.

In the third phase, the outcomes of the second phase (i.e., the proposed semiotic framework) are refined and validated through an empirical study. In this study, participants are provided a half-day tutorial to learn and to apply the proposed framework and then are asked to do an assignment (i.e., evaluate a set of interface signs with the proposed framework); this is followed up by a questionnaire related to the proposed framework. This study is conducted with a total of 23 participants. The results of this study are used to assess the quality and applicability of the proposed framework, as well as to aid in the further refinement of the framework. The outcome of this phase gives answers to research question *RQ5*.

Table 1. Linkages between the original publications and the research questions

Article	Objectives	Question(s)
Paper I	Understand the current status of semiotic research in UI design and evaluation	*RQ1*
Paper II	Explore the importance of applying semiotic concept in UI design and evaluation, and find a set of semiotic features to design user-intuitive interface signs	*RQ2*, *RQ4*, & *RQ5*
Paper III	Find a set of semiotic features to design user-intuitive interface signs	*RQ4*
Paper IV	Find a set of determinants (features) and attributes (sub-features) of user-intuitive interface signs	*RQ4*
Paper V	Explore the value of integrating semiotic concept in usability testing	*RQ3* & *RQ5*
Paper VI	Propose a semiotic framework that includes (a) a set of determinants and attributes, and (b) a set of semiotic heuristics	*RQ4*
Paper VII	Assess the quality and applicability of the proposed semiotic framework	*RQ5*

Apart from these, the research benefited from feedback obtained continuously from UI professionals, researchers, and students. The activities that also support the process of updating and refining the study design and the research outcomes include: publication of the study results and participation in relevant conferences and workshops; publications of substantiated results in journals; participation in two international doctoral consortiums; presentation of the research results at seven international conferences; teaching an advanced level course on usability testing and evaluation at Åbo Akademi University and at University of Turku; and active participation in an industry project (a 5-month project) as a usability and semiotic expert. The research methodology is discussed more comprehensively in chapter 3. Table 1 shows the linkages between the published articles and the research questions. The published articles are discussed more comprehensively in chapter 4 and attached to the end of this dissertation.

1.5 Research Scope

The thesis targets practitioners, researchers, teachers, students and people interested in design and evaluation – in particular web user interface design and usability evaluation. Explicit knowledge of specific terminology related to the area should not be required for a general understanding, but could be useful in order to fully grasp all aspects of this research (e.g., terminology related to theory of semiotic). The limited time available for the research makes it impossible to dive deep into all relevant aspects related to UI design and evaluation, as well as explore every relevant perspective related to the research questions and the research problems. It is therefore necessary to define some boundaries for the work in order to narrow the scope of the research. The scope of this research is limited by the following constraints.

The thesis is mainly focuses on web user interface design and evaluation, more specifically on web interface signs, which are a particular dimension of web interface design and evaluation (see figure 1); and thus the thesis is related to a particular kind of HCI paradigm (i.e., interaction between a web UI and its users).

As the focus of the thesis is web user interfaces, the studies presented in this thesis are carried out on web user interfaces (i.e., user interfaces of web sites and web applications) and mainly consider the web interface signs, small elements of web user interfaces.

The thesis is not about ‘web engineering’ in general, but on the activity of web user interface design and evaluation, which is a significant – but not comprehensive – part of web engineering.

The thesis does not consider interface signs for information systems in general (e.g., desktop application, games, mobile user interfaces, etc.), but only the interface signs of web user interfaces that are designed mainly for the computer/desktop.

Though the ultimate aim of the thesis is to contribute to the improvement of web usability, the research does not consider all issues related to web usability, because web usability depends on many other dimensions of interface design, e.g., web content, navigational architectures, page layout, etc. The thesis focuses mainly on interface signs and users' interpretation of web interface signs, which is the first fundamental step for designing usable UI since users interact with web applications by means of interface signs.

Moreover, the thesis does not consider user profiles for which the interaction paradigm and the interaction platform change radically (e.g. users with physical or cognitive disabilities). In such cases, users interpret the meaning of interface signs based on different processes or elements. For example, blind users need screen readers to interact; mobile users may experience a changing kind of interaction because of the changing context of use.

1.6 The structure of the Dissertation

The dissertation is organized into two parts: an overview of the dissertation and the original publications. An overview of the dissertation is described through the following chapters:

Chapter 1 presents the *Introduction* of the research that briefly discusses the research background, motivation, and research problems; the research objectives and questions; the outline of the research process and the research scope; the linkages between the original publications and the research questions; and the structure of the dissertation.

Chapter 2 presents *Theoretical Background and Related Work* that briefly introduces the relevant semiotic theories and discusses related work carried out in the field of semiotics in HCI.

Chapter 3 presents *Methodology and Study Design* that describes methodological considerations of this research that includes methodological choice and an overview of the studies that are carried out.

Chapter 4 presents *Results* that introduces the original publications by discussing the research questions investigated and the study results; and discusses the summary of the results of the whole thesis.

Chapter 5 gives the *Discussion and Conclusions* of the research that presents summarized answers to the research questions, the research contribution, implications for practice, the limitations of the thesis, and possible future research directions.

The original publications form the second part of the thesis which includes a total of seven original articles.

Chapter 2

Theoretical Background and Related Work

This chapter presents the theoretical background and related studies of semiotic in HCI. First, the relevant theories of semiotic are discussed. Then it is discussed how the concept of semiotic is applicable for web interface signs. Next the chapter discusses the relevant work carried out in the field of semiotic in HCI. Finally, a summary of this chapter is presented.

2.1 Outline of Semiotic Theories

"We live in world full of signs. Whatever our eyes take in is pervaded by signs, ranging from traffic signs to the constellation of stars in the night sky; from the silhouette of a mother's image in our dreams to the seven color bands of the rainbow. . . . Conceiving of a world without signs is impossible." (Kim, 1996)

The study of signs and significations is called semiotic (Liu, 2000). The central notion of semiotic is 'sign'. A sign is defined as a pattern of data which, when perceived, brings to mind something other than itself (Dillman, 2012). It generally takes the *"form of words, images, sounds, odours, flavours, acts or objects and even gestures"* (Chandler, 2002). The key features of considering anything as a sign are: a) it should have some meaning or stand for something else, and b) it should be interpreted by someone. In other words, a sign becomes a sign only when we invest them with meaning (Chandler, 2002; Morris, 1938). In one of his many definitions of a sign, Peirce wrote, *"I define a sign as anything which is so, determined by something else, called its Object, and so determines an effect upon a person, which effect I call its Interpretant, that the later is thereby immediately determined by the former"* (Peirce, 1931:58). Burgoyne et al. (1992) defines semiotic as *"the study of signs, signification, and signifying systems"*. Thus, semiotic is considered to be an account of the representation of a sign and its signification. In other words, semiotic is about

understanding how people design the sign and interpret the meaning of a sign or a system of signs. The semiotic theories and models provided by Ferdinand de Saussure, Charles Sanders Peirce, Umberto Eco, Charles William Morris, and Gottlob Frege are briefly presented here to give an outline of fundamental concepts of semiotic.

2.1.1 Ferdinand de Saussure's semiotic

De Saussure's theory of semiotic mainly concentrates on language and its ability to convey concepts. De Saussure (1983) develops a dyadic concept of sign that consists of (a) a *signifier* - the form a sign takes, e.g., an image, a word, a facial expression, etc., and (b) the *signified* - the concept of the sign or the mental representation/concept in response to a signifier (Eco, 1976). A *signifier* cannot exist without meaning and the *signified* cannot communicate without a signifier. A sign must process both a *signifier* and the *signified*. For example, 'Closed' could be a sign if it is interpreted by someone who encounters it on the entrance of shopping mall consisting of a *signifier* (the word closed) and a *signified* (the shop is closed for customers to buy products). If the word 'Closed' is placed at the entrance of an amusement park, it could stand for a different signified (the park is closed for visitors) (see figure 1). That means, each unique pairing of signifier and signified constitute a different sign (Chandler, 2014). In Saussure's view a sign makes sense only in relation to other signs within the system, not only on its own. In other words, the value of a sign depends on its relation to other signs within the system. As an example, de Saussure states that on the chessboard the value of each piece depends on its position (de Saussure, 1983).

Figure 4. A Saussurean dyadic model with an instance of a linguistic sign 'Closed'

Thus, the sign is more than the sum of its parts, i.e., a *signifier* and the *signified* (Chandler, 2014). De Saussure stresses that the relation between signifier and signified is arbitrary because of the principle of language (i.e., the arbitrary nature of language). He declares that *"the entire linguistic system is founded upon the irrational principle that the sign is arbitrary"*. Later Saussure introduces the degree of arbitrariness and states that *"not all signs are absolutely*

arbitrary. In some cases, there are factors which allow us to recognize different degrees of arbitrariness, although never to discard the notion entirely. The sign may be motivated to a certain extent" (de Saussure, 1983). In his opinion, there is no connection between a word and the concept it refers to other than that which is agreed by the rules of language, e.g., a cat is called a cat because we all agreed to call it a cat (O'Neill, 2005).

De Saussure stresses that the 'value' of a sign is determined by both its paradigmatic and its syntagmatic relations with other signs within the system. The syntagm and paradigm provide a structural context within which signs make sense. The syntagm is an orderly combination of signs to produce some form of meaningful whole. For example, sentences are syntagmatic, where signs are combined in an organized way to produce a meaningful statement. A paradigm is a set of signifiers or signifieds which are in some way associated with one another and are members of some defining category; and each one is significantly different from the others. For example, the set of colors: *red, blue,* and *black*, where each sign is the member of a defining category (i.e., colors) and each sign is individually different from the others. The syntagm is that of the combination of 'this-*and*-this-*and*-this' (as in the sentence, 'the T-shirt is red') whilst the paradigm is that of the selection of 'this-*or*-this-*or*-this' (e.g. the replacement of the last word in the same sentence with 'blue' or 'black'). Thus, in de Saussure's model the signification depends on the relationship between the signifier and signified, and the value of sign depends on the relationship between the sign and other signs within the system (de Saussure, 1983).

2.1.2 Charles Sanders Peirce's semiotic

A semiotic model proposed by Peirce (1931-58) consists of a triadic relationship containing the *representamen*, the *object* and the *interpretant*. The *representamen* is the form that the sign takes to stand to somebody for something in some respect, an *interpretant* is the sense made of the sign created in the mind of the perceiver, and an *object* is the actual thing the sign stands for. The 'diskette' sign (see figure 2) exemplifies the semiotic model of Peirce; the diskette icon is the *representamen,* saving the file is the *object,* and the concept that the sign evokes in the mind of the reader (i.e., the sign is for saving my document file) is the *interpretant*.

According to Price and Shanks (2005), these three levels pertain to the *form*, *meaning*, and *use of sign* respectively. Peirce's triad is also known as 'The semiotic triangle' and the terms are used as *sign vehicle*, *sense*, and *referent* (Nöth, 1990). A sign requires the existence of these constituents concurrently. It is notable that many of the communication and media theorists stresses the importance of sense-making (or the active process of interpretation) and thus

allude to semiotic triangles in which the interpreter or user of the sign features explicitly in place of *interpretant* or *sense* (Chandler, 2014). According to Chandler (2014), the role of the interpreter must be accounted for when constructing the meaning of a sign, whether Saussure's or Peirce's model is adopted, since the meaning of a sign arises in its interpretation.

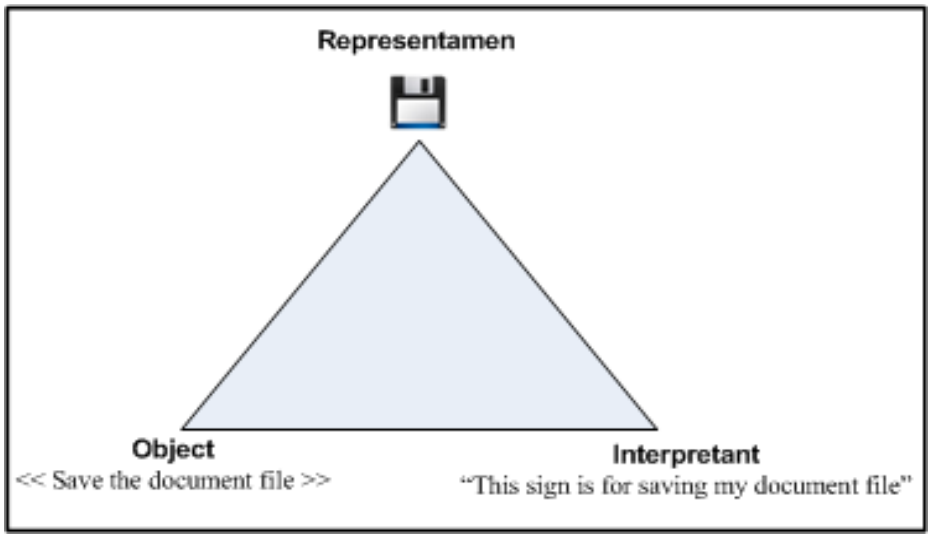


Figure 5. A Peirce's triadic model of a diskette sign

Peirce classified signs into 59,049 types of signs, but acknowledged that the most fundamental sign divisions are the *symbol*, *icon* and *index*. The relationship between the object and the representamen defines the category a sign belongs to (Ferreira, 2005). A symbolic sign does not resemble the signified, and the representamen is a fundamentally arbitrary or purely conventional sign that must be learned by the perceiver, e.g., language, national flag, etc. An iconic sign resembles or in some way imitates the object, e.g., a portrait, a cartoon, etc. An indexical sign does not represent its object but it creates a link (physically or causally) between the object and the representamen in the mind of the perceiver, e.g., smoke (natural sign), pain (medical symptom), clock (measuring instrument), etc. Peirce stresses that the three types of signs are not mutually exclusive, i.e., it would be very difficult and some argue impossible, to find any sign that belongs to absolutely one type. For example, a map is indexical (pointing to the location of things), iconic (represent the direction and distance), and symbolic (conventional symbols). Chandler (2014) stated that "signs cannot be classified in terms of the three modes (types) without reference to the purposes of their users within particular contexts". Moreover, a sign may consequently be considered as iconic by one person, symbolic by a second person and indexical by a third person. However, some relations between the *representamen* and the *object* may dominate and then it can be considered that

the sign is primarily of that relationship (or type) that dominates (Ferreira, 2005).

Peirce develops the concept of semiosis (a process of meaning making). In semiosis, the *interpretant* of a sign can become a new sign (or a new *representamen*), with a new *object* and *interpretant* of its own (Bar et al, 2004). Peirce (1931-58) stated that "anything which determines something else (its interpretant) to refer to an object to which itself refers (its object) in the same way, this interpretant becoming in turn a sign, and so on ad infinitum". This process of constructing the meaning of a sign can go on forever and thus Eco (1990) termed this process as unlimited semiosis.

2.1.3 Further Semiotic Theories

According to Umberto Eco (1976), semiotic is concerned with everything that can be taken as a sign. Eco's (1976) theory of semiotic provides: (i) a method of investigating how sign-vehicles or representamen may function as signs, and (ii) a means of understanding how a sign-vehicle may be produced and interpreted. His definition of the sign takes into account the social, cultural, and contextual issues. In his view, a sign may take on different meanings within different socio-cultural contexts. For example, the sign 'C' represents 'the English letter C' in the context of keyboard, whereas it represents 'cancel' in the context of mobile phone.

According to Gottlob Frege (1879), the sign is a logical triad consisting of: *Zeichen* (sign) for the symbol, *Sinn* (sense) for the concept, and *Bedeutung* (reference) for the object (Sowa, 2000). As an example, Frege states that both the '*morning star'* and the '*evening star'* terms refer to the same meaning or reference - the planet Venus, but their senses are very different in the way in which the planet is presented: (a) one term refers to a star seen in the morning, and (b) the other one refers to a star seen in the evening (Sowa, 2000). According to Frege (1879), sense and reference are two different aspects of the sign's meaning. Thus, there is no one-to-one relation between the sign and its meaning. A number of signs may refer to the same meaning instead of multiple meanings.

According to Charles William Morris (1938), semiotic is the science of signs. Morris's (1938) semiotic theory divided the sign into a threefold that is derived from Peirce's triadic model of semiotic: (a) *syntactic* - the formal or structural relations between signs; (b) *semantic* - the relationship of signs to what they stand for; and (c) *pragmatic* - the relation of signs to interpreters. The syntactic level is the study of how signs and combination of signs follow particular rules (Morris, 1938). The semantic level is the study of the meaning of the sign

(Morris, 1971). The pragmatic level studies the relations between signs and those who interpret them; thus it deals with the origins of the signs, their uses and the way they affect people's behaviour (Morris, 1971). In his view, semiotic extends beyond purely linguistic signs (Morris, 1971) and people are interpreters of signs (Morris, 1964). According to Morris, human action involves signs and meanings in three ways: (i) perception stage - the interpreter becomes aware of a sign; (ii) manipulation stage - the interpreter interprets the sign and decides how to respond to the sign; and (iii) consummation stage - the person responds.

2.2 Semiotic and Web Interface Signs

User interfaces are made up of many smaller interface signs (e.g., command buttons, thumbnails, navigational links, etc.) in order to convey the meaning of interface signs to the users (Ferreira, 2004; Neumuller, 2001). The interface sign in a web user interface is always an intentional sign (Ferreira, 2005). That means, designers create interface signs in order to convey some message (content/function) to users. Designers design the interface signs as an encoded form in a web user interface and users need to decode these signs in order to obtain their meaning (messages). Users interact or communicate with web user interface by means of these signs. This implies that users are required to interpret or guess the meaning of interface signs when interacting with the web interfaces in order to perform tasks or to obtain the desired information. As Derboven et al (2013) note, *"interpretation is central to human-computer interaction…..Users interpret icons, buttons, and other controls to make sense of the functionality offered by an application"*. Thus an interface sign can be said to be successful if the user's interpretation matches with the designer's assigned meaning (or the object of the sign). In other words, a user can perform a desired task accurately when the user's interpretant matches with the designer's interpretant, and inaccurately otherwise.

Semiotic is important for designing web user interfaces, since interface signs are key components of web UI and semiotic provides concepts for analyzing these interface signs. Based on the concept of semiotic theories discussed above a few important properties of interface signs can be discerned. These are: i) each interface sign has its own triadic relation: the *representamen* corresponds to the form of an interface sign, the *object* corresponds to the referential content, or underlying functionality, and the *interpretant* corresponds to the meaning (or a sign) generated in the mind of the interpreter or user; ii) there is no one-to-one link between the sign and its meaning or referential object; iii) users usually understand the meaning of interface signs through the creation and interpretation of 'signs', i.e., a semiosis process takes place in the mind of the user to understand the meaning of interface signs; and iv) the meaning of an interface sign depends on the socio-cultural context. Thus, semiotic play a key role to

design understandable web interface signs that convey their intended meaning to the users.

2.3 Relevant Work in the Field of Semiotics in HCI

Over the last few decades, semiotic has begun to emerge as an interesting area of research in HCI (O'Neill, 2005). Semiotic research in HCI employed and expanded upon prior work within a number of research areas. This section provides an overview of the related semiotic work in HCI in five different focus-areas, based on their research outcomes. The material presented below is based on a systematic literature review carried out in 2011 and a more recent survey of all relevant semiotic studies published from August 2011 to 2013. The systematic literature review included the relevant semiotic studies in HCI published from 1986 to July 2011, and was published in an international journal (see *Paper 1*). For the sake of clarity, a *critical analysis and synthesis* of relevant literature focused on semiotics in HCI (and more specifically on the topic of this thesis) can be found in *Paper I* and section 4.2.1. *Identified research gaps* are also presented in *Paper I* and section 4.2.1.

2.3.1 Semiotic Theories and Concepts in HCI

The existing semiotic theories and concepts that are related to this thesis are discussed in this sub-section.

A. Semiotic Engineering: De Souza (2005a) introduced the concept of semiotic engineering in HCI as a semiotic approach to design software artifacts in order to fulfill the system's communication goal. Research carried out on this concept since 1990 in the Semiotic Engineering Research Group (SERG) (in Rio de Janeiro, Brazil) developed the concept of semiotic engineering into a comprehensive semiotic theory of HCI (De Souza, 2013). According to the theory of semiotic engineering, human-computer interaction is a computer-mediated human communication process that involves three agents: designers, users and system. The agents are brought together at interaction time because software artefacts are viewed as a meta-communication artifact in semiotic engineering; they are a 'one-shot message' sent from the *designer* to the *user* through the *system* to achieve specific results or effects. In the scope of semiotic engineering, an effective HCI can be achieved via a two-fold communication process: a) communication between designer and system, and b) interaction between system and user (De Souza, 2005a; 2005b; 2013; De Souza et al. 2001a; 2001b). Semiotic engineering analyzes the connection between system symbols (e.g., words, icons, graphical layout, buttons, links, etc.), semantics and functions in order to understand the (designer-to-user) meta-communication. In principle, the ability of semiotic engineering is to produce successful design in order to ensure that the user receives the accurate messages sent by the

designers. In other words, the main quality of semiotic engineering is to achieve system communicability in order to convey the designer's messages effectively (obtaining the desired results) and efficiently (in an organized and resourceful way) to the system's users. Two methods have been proposed based on semiotic engineering in order to evaluate system communicability: (i) semiotic inspection method (SIM), and (ii) communicability evaluation method (CEM). The SIM is an inspection method that allows the analysts/experts to assess the communicability of software artifacts. In other words, SIM evaluates whether or not designers' messages are communicated to the users effectively and efficiently through the design choices and interactive content of software artifacts. The SIM is carried out in five steps (De Souza et al., 2006):

a) an inspection of metalinguistic signs through the online and offline help documentations and help content;
b) analysis of static signs (i.e., interface elements from the screen);
c) analysis of dynamic signs (i.e., signs emerging from the interaction with the system and its behaviour);
d) comparison and contrast of designer-to-user meta-messages identified in steps a, b and c; and finally
e) a conclusive appreciation of the quality of the overall system's communicability;

Before carrying out SIM, evaluators must understand the scope of the system to be examined and the profiles of the focused users. The CEM is a specific qualitative method that focuses on the designers' communication through user observation and analyses user interfaces based on a semiotic interpretation. The aim of the CEM is to analyze how well users are receiving the designers' message through the interfaces and to identify communication breakdowns during users' interactions with the system. The CEU is carried out in three steps (Prates et al, 2000):

a) *Tagging* - tag all problems that users encounter according to a predefined tagging scheme in order to identify all communicative breakdowns between the designer and the user. Prates et al. (2000) proposed thirteen tags, an example of a tag is: 'I can't do it?' used to tag interaction when the user is unable to achieve the desired goal.
b) *Interpretation* – tags are organized and analyzed onto HCI ontologies of problems or design guidelines. The goal of this step is to understand the higher level problems of communication breakdowns.
c) *Semiotic profiling* – interpreting the data of step *b* in semiotic terms. The goal of this step is to retrieve the original meaning of the designer-to-user communication.

In sum, the theory of semiotic engineering and both SIM and CEM methods are focusing on analysing system communicability. De Souza et al. (2006) suggest that one can start by a SIM and then proceed with a CEM, in order to analyse system communicability. These methods also contribute to system usability

since communicability refers to how effectively and efficiently the system's interface conveys the system's logic (Salgado et al., 2009). In this vein, Salgado et al. (2009) stated that "communicability problems tend to lead to usability problems, since usability tactically requires that users get the system's logic through the interfaces signs before they can possibly learn to use them, retain them, and be satisfied with interaction".

The SERG (semiotic engineering research group) lead by the De Souza has published a number of papers based on SE, SIM, and CEM that mainly focus on the communicability issues of software artifacts. For example, Salgado et al. (2009) investigate and demonstrate the applicability of SIM to analyze the ICDL (International Children's Digital Library). De Souza & Cypher (2008) and Silveira et al. (2001) show the value of semiotic engineering in interface design through case studies of (i) redesigning the CoScripter interface, and (ii) designing an online help system, respectively.

B. Semiotics of UI elements: Nadin (1988) discusses the elements of user interfaces, for example he defines the interface sign in Peirce's terms (i.e., representamen, interpretant, and object), defines the type of representation (iconic, indexical, and symbolic), discusses the type of command (prefix – specifies first the verb and the object of the operation, e.g., 'submit application', postfix, and infix), points out the matter of semiotic consistency in interface design, discusses the importance of user's model (e.g., naive or experienced) in interpreting the interface signs, etc. In his view, semiotic principles are technologically dependent when applied, i.e., signs are context sensitive. From a semiotic perspective, it is necessary to maintain a unity between the function (interpretation, content, use), syntax, and semantics in order to design an interface sign. In other words, to design a sign, one first needs to determine the content appropriately (function), then needs to translate the content/function in computing-content and memory related issues (semantics), and finally, needs to consider how this content/function can be represented (syntax). This means that, the design process is the reverse of the interpretative process that the user goes through when dealing with interface signs in a user interface (Nadin, 1988). Nadin (1988, 2001) also broadly discusses the ability of semiotic to deliver useful concepts to HCI and points out the importance of including semiotic as part of the HCI curriculum (Nadin, 2001). Nadin says that design principles are semiotic by nature, further he defines the 'design' as the structure systems of signs in such a way that it achieved the human goals, one of which is communication (e.g., communication functions of user interface). He also explicitly mentions that the user interface issues are issues of interpretation which depend on the interface signs used in a user interface. Nadin states that "*If there is a science of interface (computer interface or any other kind), then this science is semiotic….."* (Nadin, 1988). In his view, semiotic can be used as a unifying foundation in HCI from interface design to usability testing. Nadin

(2001) stated to the HCI community that *"one cannot not interact; and because interaction is based on signs,…that is, one cannot avoid semiotic"*.

C. Computer Semiotics: Andersen (1997) provides a methodological framework to analyze HCI that is rooted in semiotic, and shows how computer-based signs mediate people's interaction with computer systems. Andersen defines a user interface as *"a collection of computer bases signs, viz. all parts of system processes that are seen or heard, used, and interpreted by a community of users"* (Andersen, 1997). In his view, a computer-based sign is composed of three classes of features: a) *handling features* that are produced by the user and articulate users actions, b) *permanent features* that are generated by the computer and it is a property of the sign that remains constant throughout the lifetime of a sign token, and c) *transient features* that are also generated by the computer but that change as the sign token is used. Andersen (1997) provides some principles to programming and program analysis, e.g., perceptibility, actions belong to signs, form and substances, etc. He also classifies the computer-based signs according to the roles they can play in interface as well as propose a framework for using the interface as the main point of reference for designing computer systems. A few examples of the classification of computer-based signs are: interactive signs (e.g., buttons), actor signs (e.g., 'table of content' in Microsoft Word), layout signs (e.g., decorative signs), etc. In Andersen's view, semiotic is complementary to the mathematical perspective of natural science since semiotic focuses on the interpretative aspects. Andersen (1992) states *"It [semiotic] has nothing to say about data [sign] in itself, only in its capacity of being interpreted and used as a source of knowledge or guide for action. If you want reliable methods for calculating time complexity of algorithms or proving correctness of programs, semiotic will be a disappointment"*.

D. Organisational Semiotics: Organisational semiotics assesses the nature, characteristics and features of information and communication within organisational contexts (Stamper, 1996; Liu, 2000). Baranauskas et al (2002 p 5) define organisational semiotics as "a discipline that explores the use of signs and its social effects within a social setting". Within organisational semiotics, Stamper (1996) proposes a semiotic framework as an analytical tool that suggests that sign can be understood at six different levels: syntactic, semantic, pragmatic, physical, empirics, and social world. A few papers have treated the subject of how organisational semiotics can help to develop design concepts for user interfaces (Sjöström & Goldkuhl, 2003). For example, Connolly and Phillips (2002) showed how the most important human factor principles could be fitted into Stamper's (2000) organizational semiotic framework and also showed the benefits for this integration in interface design. Sjöström and Goldkuhl (2004) explore UI as a means to understand the communicative as well as the socio-pragmatic characteristics of information systems use. They give an explicit

emphasis on the communicative aspects of signs in order to analyse the sociopragmatic aspects of UI. Baranauskas et al (2002) propose a framework to analyse user interfaces of e-commerce applications based on the concept of organisational semiotics. They explicitly consider the underlying organization that the user interface represents to propose this framework.

E. Algebraic Semiotics: Goguen (1999) introduces algebraic semiotic for UI. Algebraic semiotic is a kind of algebraic engineering for interface sign systems. It supports the design of better user interfaces. Two basic notions are used in algebraic semiotic, that includes sign system and semiotic morphism. In another study, Malcolm and Goguen (1999) shows the applications of algebraic semiotic for UI design. In this study, they use the basic notions of Goguen's algebraic semiotic and explore its application in interface design.

2.3.2 Semiotic Frameworks in HCI

A limited number of semiotic frameworks or models are proposed for UI design and evaluation. This thesis is closely related with the W-SIDE framework developed by Speroni (2006). The W-SIDE framework is developed to design and evaluate information intensive web user interfaces. The W-SIDE framework mainly focuses on semantics of interface signs (i.e., semiotic unit) and their understanding by the end users. Speroni (2006) and Speroni et al. (2006) propose that an interface sign basically carries two layers of meaning: a) content meaning – that relates the interface signs to pre-existing knowledge of user about real-world, and b) functional meaning – that relates the interface signs to the interactive behaviour of the application. Speroni (2006) introduces the term 'Ontology' as a set of concepts or knowledge that a user should have to interpret the meaning of interface signs. For example, an interface sign 'Inbox' in an email application may be well designed in terms of color, layout, position, etc. but will not make any sense to the users who do not know what the concept of 'Inbox' refers to. In W-SIDE, this 'concept' is defined as 'ontology'. According to Speroni (2006), the most common ontologies used in information intensive websites are:

- *InterLocutor/Institution Ontology* that refers to the concepts related to the owner of the website,
- *Internet Ontology* that refers to the concepts related to the internet uses,
- *Website Ontology* that refers to the concepts related to a particular website,
- *Commonsense Ontology* that refers to the knowledge belonging to the user's background, and referring to common and everyday terms,
- *Web Domain Ontology* that refers to the concepts related to a specific web domain,
- *Context Ontology* that refers to the knowledge related to a specific context of interface signs,

- *Topic Ontology* that refers to the concepts related to the owner of the website.

In W-SIDE, a set of semiotic heuristics are proposed to design and evaluate the web interfaces; later Bolchini et al. (2009) present these guidelines as a complementary toolkit to the existing usability methods. In order to evaluate the web interfaces, W-SIDE evaluation technique carries out the following activities in a sequential order (Speroni, 2006; Speroni et al., 2006): (i) *modeling the webpages*: select the kinds of pages that give shape to the structure of the website and carry out the semiotic analysis on the selected webpages, (ii) *syntactic inspection*: carry out a syntactic inspection to investigate the sign readability, clarity, adequacy, grouping strategy, etc., (iii) *semantic inspection*: carry out the semantic inspection to evaluate the content semantics and functional semantics of interface signs, and (iv) *semiotic user testing*: finally, carry out a semiotic user test to verify doubtful results from expert inspection with the real users.

Other semiotic frameworks in HCI include the following:

- Barr et al. (2004) propose a semiotic model for user interface metaphor. They apply the Peirce's triad (representamen, object, and interpretant) to UI metaphor. This framework adopts the concept of Eco's (1976) unlimited semiosis. In this work, they propose seven relations of the user-interface metaphor, e.g., *metaphor interpretation* that represents the designer's thinking process; and holds between the metaphor and designer's interpretant.

- O'Neill and Benyon (2003) propose a semiotic model of interaction through interactive media. The model is developed based on the concept of computer semiotic (Andersen, 1997) and Eco's revised KF model (Eco, 1976). The model includes four elements: sequential and concurrent syntax, the umwelt (the mass of knowledge that a user carries into every interaction, the perception/action loop (relations between organism and environment), and information artifacts (signs that make up an interface).

- French et al. (1999) propose a semiotic framework (shared meaning design framework -SMDF) to design and develop the e-commerce applications. The SMDF framework provides support to improve the HCI performance (meaning, complexity and usability) in the domain of e-commerce applications. The framework includes a total of six interrelated layers: HCI (objects, signs, semantic and surface level complexity), local contextual cues, organizational semiotic, cultural norms, and concepts of trust and security.

- Hargood et al. (2010) propose a thematic model for capturing the semiotic relationship between terms used to tagging in web pages. The model is used for term expansion in order to improve thematic understanding of content

and tags of a system. The model is built on the concept of signifier and signified of sign system, and conational and denotation meaning.

2.3.3 Semiotic Analysis Methods for UI

Analysis of user interfaces through semiotic concepts is covered by a limited number of studies. The procedures or steps used to analyze the user interfaces and the semiotic constructs or layers involved in the existing analysis methods are summarized in table 2.

Table 2. Examples articles of analysis methods for UI analysis

Articles	Main focus of the analysis	Analysis steps and semiotics layers/ constructs
Derboven et al, 2013	To identify and analyze user interpretation of UI	Analysis performed in three phases to carry out the evaluation process: (a) semiotic analysis – carried out as an in-depth semiotic analysis to reveal how the system shapes and controls the users' meaning construction; the result of this phase is used as a baseline view that can be compared to the real users' behaviour; b) ethnographic research and matching – this phase focuses on real users' interactions to observe how users use the system and interpret the interfaces; and c) design implications – analyzes the results of previous steps to understand which elements of systems are evaluated and interpreted in different ways and how the characteristics of users and their context influence these differences. The results of this phase thus provide the design implications for the studied application.
De Souza et al., 2006,	To analyze the interface's quality of the meta-	The analysis is carried out following the semiotic inspection method (SIM) (see section 2.3.1).

	communication.	
Speroni, 2006	To design and evaluate information intensive web interfaces based on the W-SIDE framework.	The evaluation is carried out based on the W-SIDE framework (see section 2.3.2).
Scolari, 2009	A methodology to analyze web interfaces.	This approach reflects the application of semiotic in HCI. It analyzes the interfaces in four levels: plastic (surface analysis), figurative (scene analysis), communicative (receiver's position analysis in respect of the interface), and meta-communication receiver's position analysis in respect of the whole situation.
Bilotta and Pantano, 1995	An approach to analyze and classifying icons in GUI	The method involves three steps. The steps belong to three constructs of semiotic: analyze the icon in relation to itself (syntactic), then in relation to its referential objects (semantic), and finally in relation to the human interpreter (pragmatic).
Triacca et al., 2005; Bolchini & Garzotto, 2007	A usability inspection method (Milano-Lugano Evaluation Method – MiLE+)	The MiLE+ is developed for evaluating the web usability. It integrated the concept of semiotic to analyze the application-independent features of web interfaces.
Roberto and Toppano, 2009	To design and analysis the hypermedia	Four levels of signification are structured in this framework: semiotic square, semio-narrative, discoursive, and textual level.

2.3.4 Semiotic Guidelines for UI Design

A limited number of studies have been conducted to propose the guidelines or principles for user interfaces design and evaluation till 2011; they include (i) a

set of heuristics for interface design and evaluation that is proposed as a complementary tool kit to the existing usability evaluation methods (Bolchini et al, 2009); (ii) design guidelines for user interfaces in a particular application context and maintaining indexical relationship between sign and their referential object (de Souza, 1993); (iii) ten guidelines of design, diagnoses, and evaluation to make effective visual designs; the guidelines are deduced from the Peirce's ten sign types (Amare and Manning, 2006); (iv) design and evaluation guidelines for the small elements (i.e., interface signs) of a user interface (Ferreira et al., 2005; Ferreira et al., 2006); and (v) a set of general design guidelines for user interface design; guidelines are provides in four categories: navigation, iconic representation, aesthetics, and world of references (Liu et al, 1998). Very recently, a few studies are carried out focusing on interface design guidelines or principles, which include the following:

- Brejcha & Marcus (2013) propose a set of semiotic heuristics for investigating user interfaces. They carry out two heuristics inspections on two graphical design applications: one is carried out using their proposed semiotic heuristics and another one is carried out using heuristics proposed by Marcus at al. (2003). Finally, they compare the results of both studies and suggest to merge the two methods in order to achieve a best-of-both solution.

- Valdestilhas et al. (2013) discuss the importance of the semiotic principles to design the GUI for social media data spaces on the mobile phone. Their future aim is to provide an intuitive and user friendly interface capable of exploring a big data space on mobile devices, and to find ways to deal with the limits of mobile device displays.

- Oswald (2013) discusses the semiotic approaches for UI design and provides some fundamental concept on the user's perception and way of interpreting the sign meaning in a user interface.

2.3.5 Studies Related to Extending and Applying Semiotic Concepts in HCI

The other related studies have mainly investigated, evaluated, demonstrated, integrated, and explored the semiotics theories, frameworks, and design principles in HCI. For example,

- Reis & Prates (2013; 2012) assess the characteristics of SIM to understand its cost, benefits, advantages and disadvantages. They collected subjective data from novice evaluators and from the authors (representing SIM experts) of SIM using questionnaires and interviews respectively, and then

used a grounded theory approach to analyze the collected qualitative data. The result shows useful insights and important characteristics of the SIM method; for example, SIM is very useful for evaluating the communicability though it demands much time and effort to learn and apply.

- Pender & Lamas (2013) explore the contributions of semiotic engineering in interaction co-design through a case study. They show that the semiotic approach (SIM) used in a formative evaluation process provides useful feedback to the design process, which in turn helps to improve the interaction design.

- In her doctoral dissertation, Rousi (2013) uses the concept of cognitive semiotic to understand the semantic connection between design syntax, context and the mentally represented experience of users. She found that the study of user experience is in fact the study of signs. In other words, she observed that user experiences are semiotic interactions. Rousi (2013) states *"Design encounters: perception (apperception), usage and overall sentiments recalled from the experiences all rely on symbols, their presentation, interpretation and re-presentation, in order to operate"*.

- Tancredi & Torgersson (2013) apply the SIM on computerized patient record systems. The results show that SIM helps to identify major usability issues related to the navigation, workflow and way findings. They also suggest that SIM needs to provide guidelines to handle the extensive amount of qualitative data collected during the application of the SIM.

- Gatsou et al. (2012) analyse graphic representation by means of icons for mobile interfaces. They use Peirce's concept of classifying signs into icons, indexes, and symbols; and Nadin's (1988) concept of sign representation (indexical, symbolic, and iconic) and their concrete to abstract representation. They carried out a paper-based icon recognition test with 60 participants and found that i) graphical representation affects the recognition rate of icons and influences user perception, and ii) the age of the users also has an impact on icon recognition.

- Derboven et al (2012) carry out an evaluation study on a multi-touch interface following the communicability evaluation method (De Souza et al., 2009) to analyse multi-touch applications in order to obtain insights on users' understanding and uses of multi-touch interfaces. Based on this study, in another article Derboven (2013) suggests that transfer of an evaluation method from one context to another needs to be done with care as he found some difficulties (hidden bias) to apply the CEM into multi-

touch interface design, which (CEM) is originally developed for analyzing the interfaces of software artifacts.

- Reis and Prates (2011) carry out a systematic literature review to investigate whether the SIM (De Souza et al., 2006) is applicable as a technology and domain independent method. A total of 21 papers were reviewed in this study. The study results show that SIM is independently applicable in terms of technology and domain.

- Bento et al. (2011) explore the use of semiotic engineering theory in the design of user interfaces for different platforms (desktop, tablet PC, and handheld) used to control a mobile robot. They also develop a common interaction model for each interface based on a set of sign classes for human-robot interaction.

- Cameron et al. (2011) examine the role of text in augmented reality user interfaces from a social semiotic (that analyzes the language, culture and communication) perspective. They suggest that the role of text in augmented reality can differ and depends on the type of text-image interaction.

- Bento et al. (2009) investigate the applicability of SIM in human-robot interface. They apply SIM to a robot user interface that is developed for controlling a robot named e-Puck. They find that SIM is applicable in a robot interface to assess its communicability.

- Valente et al. (2008; 2009a; 2009b) explore the communication issues of mobile phone interfaces for games. They carry out an exploratory study on non-visual mobile phone interfaces for games. They use the semiotic engineering principles and focus on issues of communication through signs. The study results point to a number of issues for future research abut mobile gaming accessibility, e.g., how hearing and touch jointly or separately affect the sense of presence and immersion.

- Hynes & Janson (2007) extend the semiotic analysis (Tsotra et al., 2004) of two mobile phone companies marketing efforts to show how customers from different cultural background interpret the advertisements and make sense of the products.

- Kjeldskov (2002) simplifies the mobile interfaces based on a semiotic perspective. He shows that mobile interfaces can be simplified by increasing the spatial and temporal indexicality based on a semiotic approach to information representation.

2.4 Chapter Summary

The brief introduction of semiotic theories makes it clear that the concept of semiotic is quite applicable to study the 'interface signs' of web user interfaces (as discussed in section 2.2). Since, interface signs in a UI stand for conveying meanings (e.g., content, function, etc.) to users and users need to interpret the signs to understand their meaning. The key researchers' works (introduced in section 2.3) also focus on interface signs and show how the concept of semiotic deals with the design of interface signs, e.g., Nadin (1988) discusses the elements of interface signs, De Souza (2005) shows how the interface elements (e.g., static signs) of user interfaces convey the designers' messages to the users, Andersen (1997) sees the computer systems as a system of signs, and Speroni (2006) introduces the concept of ontology to design and evaluation of interface signs.

The above discussion on semiotic theories, key researchers' works, and other related semiotic work in HCI shows that semiotic research in HCI expanded upon prior work within a number of areas, such as (a) providing semiotic frameworks and models for UI; (b) providing semiotic approaches to analyse the UI; (c) providing semiotic guidelines, principles or heuristics for UI; (d) applying semiotic concepts to assess, integrate, evaluate, explore, and demonstrate the semiotic theories, frameworks, and design principles in HCI; and (e) describing new concepts, theories, properties, etc. from a semiotic perspective in HCI. These make it clear that semiotic has a significant role as well as accepted value in HCI research, especially to design the understandable user interfaces.

Although the existing semiotic frameworks, models, analysis methods, and guidelines have their own merits, the systematic review (*Study I* - carried out in 2011) outlined further research opportunities as a response to identified research gaps, such as developing more complete and generalized guidelines and frameworks for UI design and evaluation, applying semiotic concepts in usability evaluation, and giving more attention to the validation of the semiotic frameworks and guidelines for interface design and evaluation. Thus, the thesis is carried out to address these research gaps to a certain extent.

Moreover, since the aim of the thesis is to gain fundamental insights to design and evaluate the interface signs, in order to make them intuitive for end users and to improve overall web usability; the theoretical concept of the fundamental semiotic theories are used in the thesis as a background theory, and in a broader sense, the thesis falls within the theoretical realm of Semiotic Engineering (De Souza, 2005a) and Computer Semiotic (Andersen, 1997). The thesis is different or extends from other related work in a sense that it focuses particularly on web interface signs, and not on other design, evaluation or communicability

dimensions of web interfaces. The contribution of the thesis in relation to related work is discussed more in section 5.2.

Chapter 3

Methodology and Study Design

This chapter aims to discuss the methodology followed in the research. First, the chapter introduces the principal methodology called the design science research (DSR). Thereafter, the chapter discusses how the research follows the principles, guidelines, and process steps of DSR. Next an overview of the studies carried out is presented. Finally, presents how the DSR process is followed to address the research questions.

3.1 Design Science Research (DSR) Methodology

Design science research (DSR) is one of the most widely used research approaches in engineering, computer science, and information systems research. Design science research, as conceptualized by Simon (1996), focuses on the creation of innovative IT-artifacts to solve real-world problems. Hevner & Chatterjee (2010) define DSR as follows: "Design science research is a research paradigm in which a designer answers questions relevant to human problems via the creation of innovation artifacts, thereby contributing new knowledge to the body of scientific evidence. The designed artifacts are both useful and fundamental in understanding that problem". DSR thus provides new knowledge through the design of innovative artifacts and the evaluation of performance of these artifacts (Vaishnavi and Kuechler, 2004; Hevner et al., 2004; March & Storey, 2008). In a broader sense, the definition of an artifact includes any designed object that provides a solution to an understood research problem (Peffers et al., 2008). The artifacts that a DSR can include are (a) constructs–conceptual vocabulary of a domain in which problems and solutions are defined and communicated; (b) models–which represent a real world situation by means of constructs; (c) methods–which define a set of steps to solve problems; (d) instantiations–which operationalize the constructs, methods, or models in working systems; (e) new theories; (f) social innovations; (g) new properties of technical, social or informational resources; and (h) new design and

developments models (March & Smith, 1995; Gregor 2002; March & Storey, 2008; Ellis & Levy 2010).

A number of papers have proposed processes for carrying out DSR, including Peffers et al (2008), Archer (1984), Takeda (1990), Vaishnavi and Kuechler (2004), Hevner et al. (2004), and Nunamaker et al (1990). Peffers et al. (2008) synthesized the process elements proposed by other IS scholars, and found that the scholars to a large extent agree on common process elements. As a result of their synthesis, Peffers et al. (2008) proposed a process model that consists of six activities that include: (a) problem identification and motivation, (b) definition of solution objectives, (c) design and development, (d) demonstration, (e) evaluation, and (f) communication. A distinguishing feature of their DSR process model is that research can get initiated at almost any step, such as problem-centered initiation (refers to starting research with activity *a*), objective-centered solution (refers to starting research with activity *b*), design and development centered initiation (refers to starting research with activity *c*), and client/context initiation (refers to starting research with activity *d*).

The aim of this research is to provide semiotic means to design and evaluate web interface signs to improve system usability. In order to achieve this aim, the present research develops a semiotic framework called the Semiotic Interface sign Design and Evaluation (SIDE) framework. Therefore, the methodology followed in the research is based on the DSR approach developed by Peffers et al. (2008). The DSR methodology includes three elements for design science research (Peffers et al., 2008) that are followed throughout: (i) principles that defined the design science research, (ii) practice rules for design science research, and (iii) a process model for conducting the design science research. What follow are the key elements of DSR methodology and their use in this research.

3.1.1 Principles of DSR

Design science research is fundamentally a problem-solving process (Hevner & Chatterjee, 2010). DSR creates artifacts or innovations that define the ideas, technical capabilities, practices, and products. These artifacts or innovations provide means to analysis, design, implementation, use, and management of information systems efficiently and effectively (Denning, 1997; Tsichritzis, 1997). A fundamental principle of DSR stated by Hevner et al. (2004) is that "knowledge and understanding of a design problem and its solution are acquired in the building and application of an artifact". In short, DSR *creates* and *evaluates* IT artifact intended to *solve* an understood research problem and

follows a *rigorous process* to create the artifacts. The present research process follows the principles of DSR in the following ways:

(i) *Creates an artifact to solve identified problems*: This research *creates* an artifact (i.e., the SIDE framework) intended to *solve* an identified research problem (i.e., to provide semiotic means to design and evaluate user-intuitive interface signs for improving system usability). The SIDE framework is used for designing and evaluating the web interface signs so that they are intuitive for end-users, which in turn improves web usability. The framework incorporates a number of determinants (features or themes) and attributes (sub-features or sub-themes) of user-intuitive interface signs, and a number of semiotic heuristics or guidelines to design and evaluate user-intuitive interface signs. Thus, the artifact has a profound impact on the interface design and evaluation. As well, it improves the ease-of-use or usability of web systems.

(ii) *Follows a rigorous process*: To make this design research rigorous, a set of empirical studies are carried out following the activities of the DSR process model described by Peffers et al. (2008) and the DSR guidelines described by Hevner et al. (2004) in creating the SIDE framework. The DSR guidelines, DSR process models and the studies are discussed in section 3.1.2, 3.1.3, and 3.2, respectively.

(iii) *Evaluates the created artifact:* The SIDE framework is evaluated to assess its quality and applicability. The performance of the SIDE framework is measured when the framework is applied to design and evaluate the user-intuitive interface signs. A subjective assessment is carried out to assess the contributions of the SIDE framework from the evaluators' perspective.

3.1.2 Practice Rules for DSR

Hevner et al. (2004) provides seven guidelines to carry out DSR that constitutes characteristics of good design science research (Peffer et al., 2008). Table 3 shows how this research follows the guidelines of DSR discussed by Hevner et al. (2004).

Table 3. Guidelines of DSR and how this research follows the guidelines

Guidelines	How the research follows the guidelines
Design as an artifact	The SIDE framework is created as an artifact for designing and evaluating the web interface signs to improve system usability.
Problem relevance	The research problems, identified through a systematic review and an empirical study, are relevant to the design of user-intuitive web interface signs. Users interact with web applications by means of interface signs. Users' inaccurate interpretation of the meaning of interface signs and users' difficulties in interpreting the meaning of interface signs lead users to create usability problem(s) and to perform their task with low performance and low satisfaction; this in turn impacts the ease-of-use or usability of web systems. A solution to these problems will definitely provide knowledge and understanding that enable UI practitioners to apply the solution effectively and efficiently in designing and evaluating the web user interfaces. Hevner et al. (2004) stated that the relevance of any DSR effort is with respect to a constituent community; for example, practitioners who design, implement, and evaluate the information systems are members of a constituent community for IS researchers. The UI practitioners focus on the design, development, and evaluation of information systems in order to improve the ease-of-use or usability of information systems, and thus can be considered as members of the constituent IS community. The research problems thus are relevant for information systems research; more explicitly related to the design and evaluation of user interfaces of web information systems.
Design evaluation	The utility, quality, and efficacy of the SIDE framework are demonstrated via empirical studies. The research evaluates the performance (e.g., thoroughness, validity, effectiveness, efficiency, and reliability) of the SIDE framework, and assesses the contributions of the SIDE framework from the evaluators' perspective.
Research contribution	The contributions of the research are the SIDE framework as a designed artifact, the evaluation results of the SIDE framework in terms of performance measurement, and the contributions assessment. The artifact incorporated a set of determinates, attributes, and heuristics to design and evaluate

	web interface signs. In the evaluation, this research also shows how the framework can be used to design and evaluate web user interfaces. These contributions advance practitioners' understanding of how best to design and evaluate web user interfaces from a semiotic perspective in order to improve web usability. The research contributions are discussed in more detail in chapter 4.
Research rigor	The research carries out a systematic literature review and six empirical studies (see table 4). The studies are carried out following the DSR process activities described by Peffers et al. (2008). Empirical studies are conducted both to create the artifact (the SIDE framework) and to evaluate the artifact. Section 3.2 provides a comprehensive discussion on how the empirical studies are designed and carried out to propose, refine and validate the SIDE framework.
Design as a search process	Iteration is a central property of design science research (Hevner et al., 2004). A number of studies that are carried out continuously sought to find the semiotic features or instruments (i.e., determinants, attributes, and/or semiotic heuristics/ guidelines for user-intuitive interface sign design and evaluation) and to evaluate the derived semiotic instruments to observe their impact. These iteratively occurred over a period of 36 months. The resultant set of semiotic instruments is triangulated to different semiotic levels to propose the SIDE framework. Again, a study is carried out to assess the quality and applicability of the SIDE framework. The results of this evaluation study are used to refine and update the SIDE framework. Thus, the research is iterative.
Communication of research	The outcomes of the research are presented in different forums or conferences related to (a) information systems (e.g., IRIS 2011, MCIS 2011, and MCIS 2012); (b) human-computer interaction (e.g., IHCI 2012 and HCII 2013); and (c) semiotic in informatics (e.g., ICISO 2011 and ICISO 2014). A total of 17 papers are published based on the research in international conferences, seminars, and journals, and as a book chapter and technical reports (see the complete list of original publications in page 105, and the list of original publications included in this dissertation in page xiii). The framework is also communicated to practitioners in evaluation study.

3.1.3 Procedures for DSR

A systematic literature review and six empirical studies are carried out in this research. The activities of the DSR process model (Peffers et al., 2008) were followed to design and conduct these studies (see figure 6).

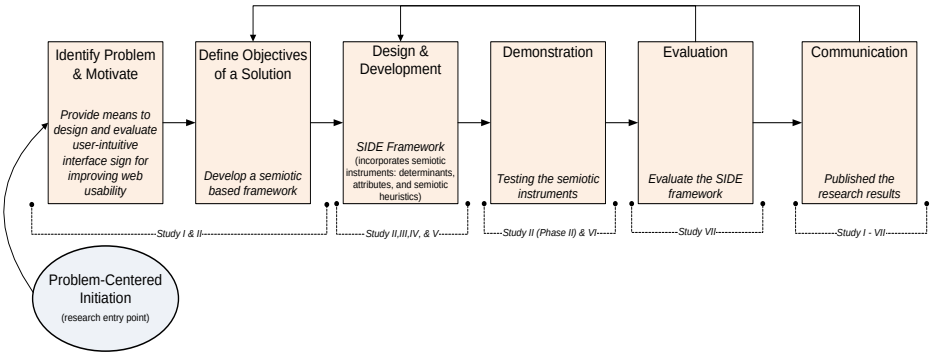


Figure 6. The DSR methodology process for this research

A brief overview of the studies are presented in table 4 and discussed in more comprehensively in section 3.2. Next we discuss how the studies are carried out following the DSR process activities.

(a) Problem identification and motivation: Our research specifies research problems and justifies the need and the value of a solution through the *Study I* and *Study II (Phase I)*. *Study I* is carried out to understand the current status (i.e., research strengths, gaps, and opportunities for further research) of semiotic research in UI design and evaluation. In *Study II (Phase I)*, a usability test (UT) is carried out followed by a sign test (a test to find the users' interpretation accuracy of the meaning of interface signs) to observe how users perform tasks in the UT when their interpretation accuracy with task-related signs is not accurate. This study shows that users interpret the meaning of interface signs accurately when the signs are intuitive for them; user performance is high when their interpretation accuracy with task-related signs are accurate, and users' interpretation accuracy of interface signs impact the overall web usability. The studies find that further research is needed to investigate and find the fundamental issues related to the design and evaluation of user-intuitive interface signs from a semiotic perspective in order to improve web usability. Thus, the research identifies the research problems and justifies the solutions with two studies.

Table 4. An overview of the studies carried out in this research

Study	Study theme	Data collection	Data-analysis
Study I	- To find the research gaps, strengths, and challenges for future research.	Systematic literature review	Summarizing & synthesizing
Study II (Phase I)	- To observe how user interpretation of interface signs affects web usability. - To show the significance of applying semiotic concept in UI design and evaluation. - To find a set of semiotic features or instruments for user-intuitive interface sign design and evaluation.	Observation (UT lab), Interviews, Questionnaires (pre-test, post-test, post-task)	Descriptive statistics; Users' behaviour analysis
Study II (Phase II)	- To show the significance of applying semiotic concept in UI design and evaluation. - To test the effectiveness of semiotic instruments observed in Study II (Phase I).	Interviews	Descriptive statistics; Inferential statistics
Study III	- To find a set of semiotic featuress for user-intuitive interface sign design and evaluation.	Observation (UT lab), Interviews, Questionnaires (pre-test, post-test, post-task)	Descriptive statistics; Users' behaviour analysis
Study IV	- To find the semiotic instruments for user-intuitive interface sign design and evaluation.	Expert (analytical) inspection	Summarizing & synthesizing; Descriptive statistics;

			Inferential statistics
Study V	- To find the semiotic instruments for user-intuitive interface sign design and evaluation.	Interviews, Questionnaires (pre-test)	Descriptive statistics; Qualitative analysis
Study VI	- To assess the value of integrating semiotic concept in usability testing - To test the effectiveness of semiotic instruments	Observation (UT lab), Interviews, Questionnaires (pre-test, post-test, post-task)	Descriptive statistics; Users' behaviour analysis
Study VII	- To evaluate the SIDE framework	Problem-solving assignment (expert inspection), Interviews, Questionnaires	Descriptive statistics; Qualitative analysis

(b) *Define objectives of a solution*: *Study II* (Phase II) shows that considering semiotic perception in designing interface signs improves the users' interpretation accuracy of the meaning of interface signs, and also improves the intuitiveness of interface signs. Thus, *Study I* and *Study II* show that semiotic has a significant role in the design and evaluation of web interface signs. Based on the results of these studies, the objective of this research is defined as: *to find semiotic means to provide valuable insights for designing and evaluating user-intuitive web interface signs in order to improve web usability.* The major challenges to accomplish this objective include (a) finding the factors in the design of user-intuitive interface signs, (b) finding what kind of presupposed knowledge users have to interpret the meaning of interface signs, (c) finding how the intuitiveness of interface signs for end users can be evaluated, and (d) finding how semiotic can be integrated into the usability evaluation to assess the intuitiveness and problems of interface signs. Thus, a solution has been offered, i.e. to provide a semiotic framework for designing and evaluating user-intuitive interface signs to improve system usability.

(c) *Design and development:* The main artifact, the SIDE framework, is created based on a series of four empirical studies (*Study II, Study III, Study IV,* and

Study V). The determinants and attributes for user-intuitive interface signs, derived from the empirical studies, are triangulated to the semiotic levels to construct the SIDE framework. The SIDE framework includes (i) a set of determinants and attributes of interface sign design and evaluation, and (ii) a set of semiotic heuristics for interface sign design and evaluation. The SIDE framework encompasses five semiotic levels: syntactic, pragmatic, social, environment, and semantic. The main goal of the SIDE framework is to provide support for designing and evaluating user-intuitive interface signs to improve web usability. The SIDE framework is thus created for (a) designing the interface signs to be intuitive for end users; (b) assessing the intuitiveness of interface signs to end users; (c) finding problems with interface signs; (d) providing possible design solutions to improve the intuitiveness of interface signs; and (e) integrating semiotic features into usability evaluation processes to improve system usability.

(d) *Demonstration*: A number of semiotic features or instruments (i.e., determinants, attributes, heuristics) identified preliminary from *Study II (phase I)*, *Study III*, and *Study IV* are demonstrated to assess the effectiveness and usefulness of these instruments. For example, the semiotic instruments found from *Study II (phase I)* are used to redesign a number of signs in *Study II(Phase II)*, and the users' interpretation accuracy and the intuitiveness of interface signs improved for the redesigned signs are observed. *Study VI* demonstrates the ways semiotic can be integrated into usability testing to improve the system usability. Thus this research tests the effectiveness of semiotic instruments for improving the system usability through *Study II* (*phase II*) and *Study VI*.

(e) *Evaluation*: An empirical study is conducted (*Study VII*) to evaluate the SIDE framework to assess and measure how well the artifact supports a solution (e.g., improve the interface signs' intuitiveness, evaluate the intuitiveness of interface signs, and recommend design solution for the problematic signs). In this study, the performance of the SIDE framework for evaluating the interface signs (i.e., to evaluate the intuitiveness of interface signs and to find the problems of designing interface signs intuitive for end-user) is evaluated. The metrics used to evaluate the performance of the SIDE framework are thoroughness, validity, effectiveness, efficiency, reliability, learnability, appropriateness, and accuracy. A subjective assessment is also carried out to assess the valuable insights and important characteristics of the SIDE framework from the evaluators' perspective. The outcomes of this evaluation are used to refine and update the SIDE framework.

(f) *Communication*: The present research resulted on articles in academic journals, academic conference proceedings and as a book chapter and technical reports. The results are published at different points of research progress in order to update or refine the research objectives, to identify the appropriate semiotic features or instruments to develop the SIDE framework, and to design the research studies.

3.2 Overview of Studies

3.2.1 Overview of Study I Design

Study focus: Groundwork for semiotic in HCI.

Methodological overview: The study follows a systematic literature review process described by Kitchenham (2004). The following four steps are followed: firstly, a comprehensive search is performed to identify and select primary studies. Search keywords are used to search the bibliographic databases (e.g., IEEE Explorer, AISeL digital library, ACM digital library) and Google. A manual bibliographic search is also performed to select the related studies. The preliminary search offers approximately 1000 articles. Secondly, a search with an inclusion and exclusion criteria is carried out to select the most relevant studies. A total of 65 articles, published during the period of 1986 – July 2011 are finally selected for review. Third, data extraction is performed following a data extraction strategy to extract data into the following six themes: (a) aims and findings (e.g., what were the main findings?); (b) method (e.g., was any usability evaluation carried out?); (c) contextual consideration (e.g., was the studied application developed for a mobile or for a desktop?); (d) outcome validation (e.g., were the findings of the research evaluated?); (e) benefit obtained (e.g., what were the goals or benefits?); and (f) publication year (e.g., which year the selected article was published). Finally, the review data is summarized and synthesized. The summary data are generated by tabulating results against stated questions that belonged to each theme of data extraction, and then the resultant data is synthesized.

Contribution: The review study identifies the types of semiotic research that have been employed in UI design and evaluation, and the areas where available evidence is insufficient and further studies are required. This study contributes to the research question *RQI*; and to the original publication *Paper I*.

3.2.2 Overview of Study II Design

Study Focus: Initial confirmation of benefits of applying semiotic concept in usability evaluation, and development of semiotic features to design and evaluate interface signs.

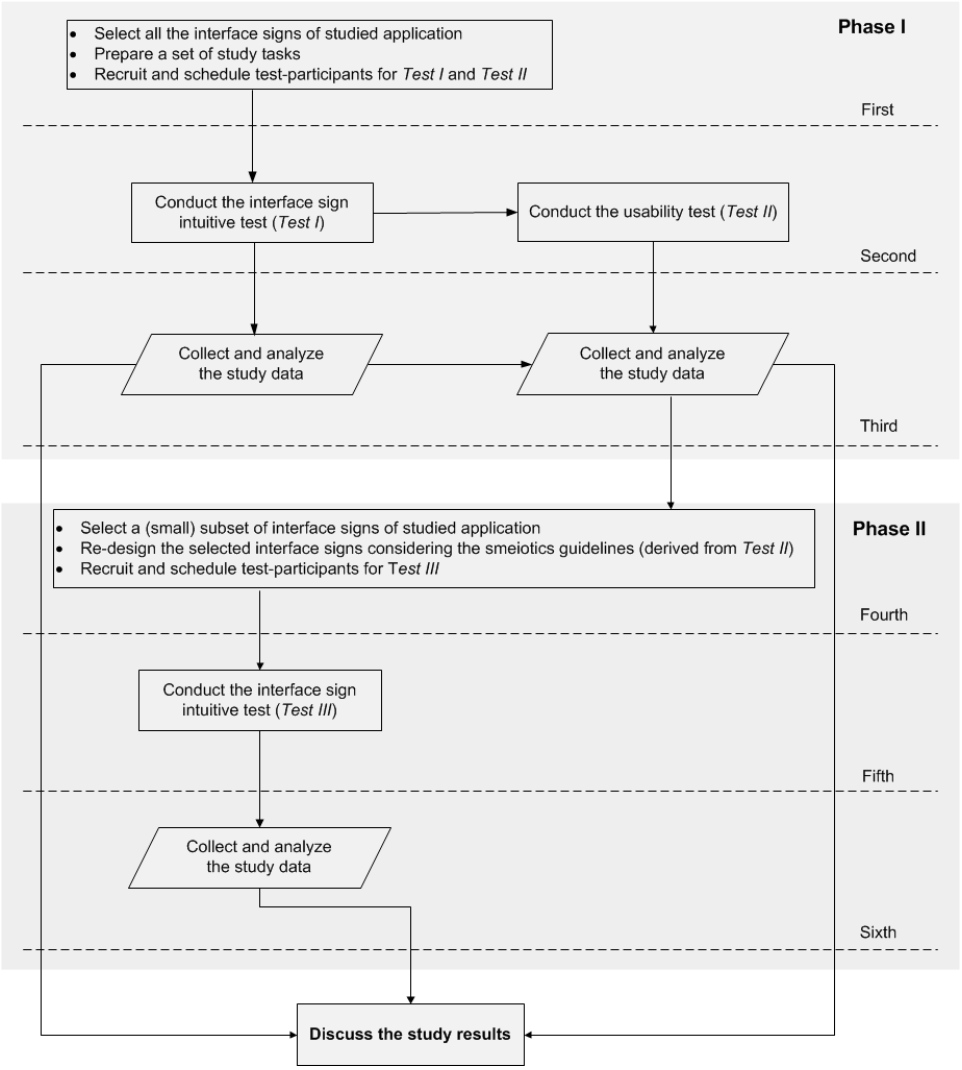


Figure 7. Methodological overview of *Study II*

Methodological overview: A total of three user tests are conducted in two phases – *Phase I* and *Phase II*. The tests are conducted on a web application (the online Ovi calendar) in Finland. Two groups of 7 and 10 participants are recruited to carry out the *Phase I* and *Phase II* of this study, respectively. An interface sign

intuitive test (*Test I*) and a usability test (*Test II*) are carried out sequentially for each participant in *Phase I*. A second interface sign intuitive test (*Test III*) is conducted in *Phase II*. The data of *Phase I* is analyzed to find out how accurate the users' interpretations are, their impact on the system's usability, and to find a set of semiotic guidelines for interface sign design and evaluation. The data of *Phase II* is analyzed to find out if the users' interpretation accuracy is improved and if their intuitiveness scores are improved after they are re-designed according to the semiotic guidelines. The methodological overview is presented in figure 7.

In *Test I,* a list of interface signs of the Ovi calendar is presented (with context and without context) to the test subjects; test subjects are asked to tell for every sign: what they thought the sign meant or what action would be the result from it. In *Test II*, to perform a usability test with each participant, the following activities are followed: (i) the given application and the test setup are briefly introduced; (ii) activities during test sessions consisted of observing users performing their tasks in a usability test laboratory; (iii) test user activities are video-recorded; (iv) the video recordings of the test sessions are examined and coded using data-logging software (Noldus Observer 5.0) to obtain test data; (v) further data is collected from pre-test, post-test and post-task questionnaires. In *Test III*, a set of interface signs of the Ovi calendar are redesigned using the semiotic guidelines. Page snapshots of the redesigned signs' and the original signs' are randomly presented to each participant. Participants are asked to interpret the meaning of the original and the re-designed interface signs. They are also asked to give a perceived intuitiveness score (1 - 7; 1: very intuitive, 7: not intuitive) for each sign.

Data collection and analysis: Both qualitative and quantitative data is collected through in observations in the UT lab, through questionnaires (pre-test, post-test, and post-task), and through structured interviews. Following an empirical research approach, descriptive statistics, inferential statistics, and users' behavior analyses are used to analyze the study data.

Contribution: This study shows (a) how users' interpretation of interface signs impact web usability, and (b) the significance of semiotic concept in UI design and evaluation. The study also provides a set of semiotic features for user-intuitive interface sign design. These semiotic features are later considered as the determinant and attribute to propose the SIDE framework. This study thus contributes to the research questions *RQ2, RQ4,* and *RQ5*, and to the original publications *Paper II* and *Paper VI*.

3.2.3 Overview of Study III Design

Study Focus: Development of semiotic features for user intuitive interface sign design and evaluation.

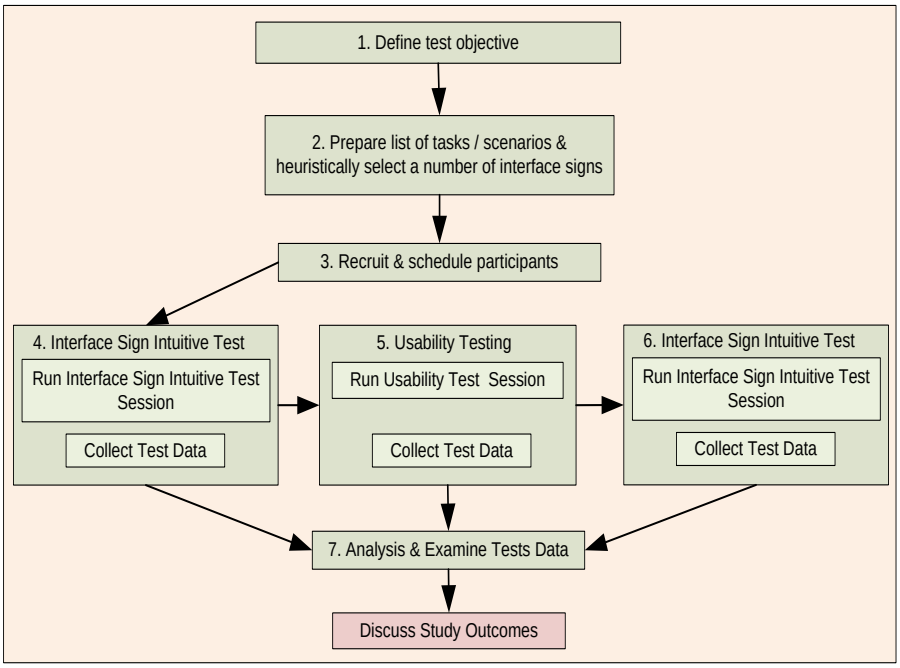


Figure 8. Methodological overview of *Study III*

Methodological overview: Three user tests are carried out in this study following a sequential order: first conduct an Interface Sign Intuitive Test (ISIT1), next carry out usability testing, and finally the second Interface Sign Intuitive Test (ISIT2). These tests are conducted on an online based e-health application in Finland. A total of 4 hospital nurses are recruited as test-participants. A methodological overview is presented in figure 8. The usability test is carried out to observe how users perform the given tasks, to find the usability problems and to recommend design solutions. In usability testing, participants are asked to perform a number of tasks. The sign tests (ISIT1 and ISIT2) are carried out to understand the users' interpretations of interface signs and their interpretation accuracy to understand the meaning of interface signs. For the sign tests, a total of 24 interface signs are chosen heuristically; the signs are chosen that seem most important in evaluating the usability of the studied application. Participants are not informed in advance that the sign test will be presented to them a second time. In sign tests, the selected interface signs are printed on separate cards in natural size and they are presented to the subjects one by one. The subject is told that she will be presented some signs that appear in the application's interfaces

and her task is to tell for every sign: what the sign means or what would happen from it; why she thought as she did, and how certain she was of her assessment. The tests are audio-video recorded.

Data collection and analysis: Study data is collected through observations in the UT lab, through questionnaires (pre-test and post-test), and through structured interviews. Following an empirical research approach, descriptive statistics and user' behaviour analyses are used to analyze the study data.

Contribution: This study provides a set of semiotic features for designing and evaluation of web interface signs. These features are incorporated as determinates and attributes to propose the SIDE framework. The study thus contributes to research question *RQ4*, and the original publications *Paper VI*.

3.2.4. Overview of Study IV Design

Study Focus: development of semiotic features for user intuitive interface sign design and evaluation.

Methodological overview: An expert (analytical) inspection is carried out to investigate issues that make interface signs intuitive for end-users. The inspection is carried out of a total of 202 interface signs and their older versions (a total of 404 web interface signs), which are retrieved from 20 websites and their historical versions. This study mainly investigates which sign (the re-designed sign or the older version of this sign) is more intuitive, and notes the features of interface sign design that have an impact on their intuitiveness. The following types of data are collected from this study: (a) *level of difficulty or intuitiveness experienced* in interpreting the meaning of interface signs; (b) *type of sign*; (c) *web sign ontology*; and (d) *other features* related to the intuitiveness of interface signs. A light-weight focus group discussion is also conducted to amend the data type and data collection process before starting to collect the study data.

Data collection and analysis: The study data is collected through an expert inspection. The study data is synthesized and then analyzed using descriptive and inferential statistics.

Contribution: This study provides a set of semiotic features for designing and evaluation of web interface signs. These features are considered to propose the SIDE framework. The study thus contributes to research question *RQ4*, and the original publications *Paper III* and *Paper VI*.

3.2.5 Overview of Study V Design

Study Focus: Development of semiotic features for user-intuitive interface sign design and evaluation.

Methodological overview: An empirical study is conducted with 26 test-participants in Finland. The data is collected through semi-structured interviews and questionnaires (pre-test). A total of 72 interface signs, select from web user interfaces (i.e., user interfaces of online calendar applications, email applications, university websites, and museum websites), are presented to test-participants in two arrangements (i.e., signs without context and signs with context); they are asked to respond to a number of questions for each interface sign, such as 'what could be the referential meaning of this sign?', 'why do you think this (user's response to the first question) is the meaning of this sign?', 'how complicated or difficult to interpret this sign (score: 1(very easy) – 7(extremely difficult))?', and 'how certain or confident are you that you are correct in your interpretation (score: 1(very low) – 7(very high))?'. Each test is conducted one by one, i.e., participants are interviewed individually. The study data is analyzed by descriptive statistics and through qualitative analysis.

Data collection and analysis: The study data is collected through semi-structured interviews and questionnaires (pre-test). Descriptive statistics and qualitative analysis are used to analyze the study data.

Contribution: This study provides a set of semiotic features for designing and evaluation of web interface signs. These features are considered to propose the SIDE framework. This study thus contributed to research question *RQ4*, and the original publications *Paper IV* and *Paper VI*.

3.2.6 Overview of Study VI Design

Study Focus: Assess the value of integrating semiotic concept in usability testing.

Methodological overview: This study compares the outcomes of three user studies. The primary purpose of the studies is to find any usability problems and recommend design solutions. The first study is a usability test that is conducted on a web application (the Ovi calendar) with 4 test-participants in Finland. The second study is the *Phase I* of *Study II* (discussed in section 3.2.2) that is conducted through two user tests: Interface Sign Intuitive Test (ISIT), and a usability test. These tests are conducted sequentially on the same web application (the Ovi calendar) with 7 test-participants in Finland. The third study is the *Study III* (discussed in section 3.2.3) that is conducted through three user tests: Interface Sign Intuitive Test (ISIT1), a usability test, and a second

Interface Sign Intuitive Test (ISIT2). These tests are conducted sequentially on an e-health application with 4 health care professionals as test-participants in Finland. Data collected from these studies is synthesized, examined, and compared to achieve the study objectives. A methodological overview is presented in figure 9.

Data Collection and Analysis: The study data is collected through observation in the UT lab, through questionnaires (pre-test, post-test, and post-task), and through structured interviews. Following an empirical research approach, descriptive statistics and user' behaviour analyses are used to analyze the study data.

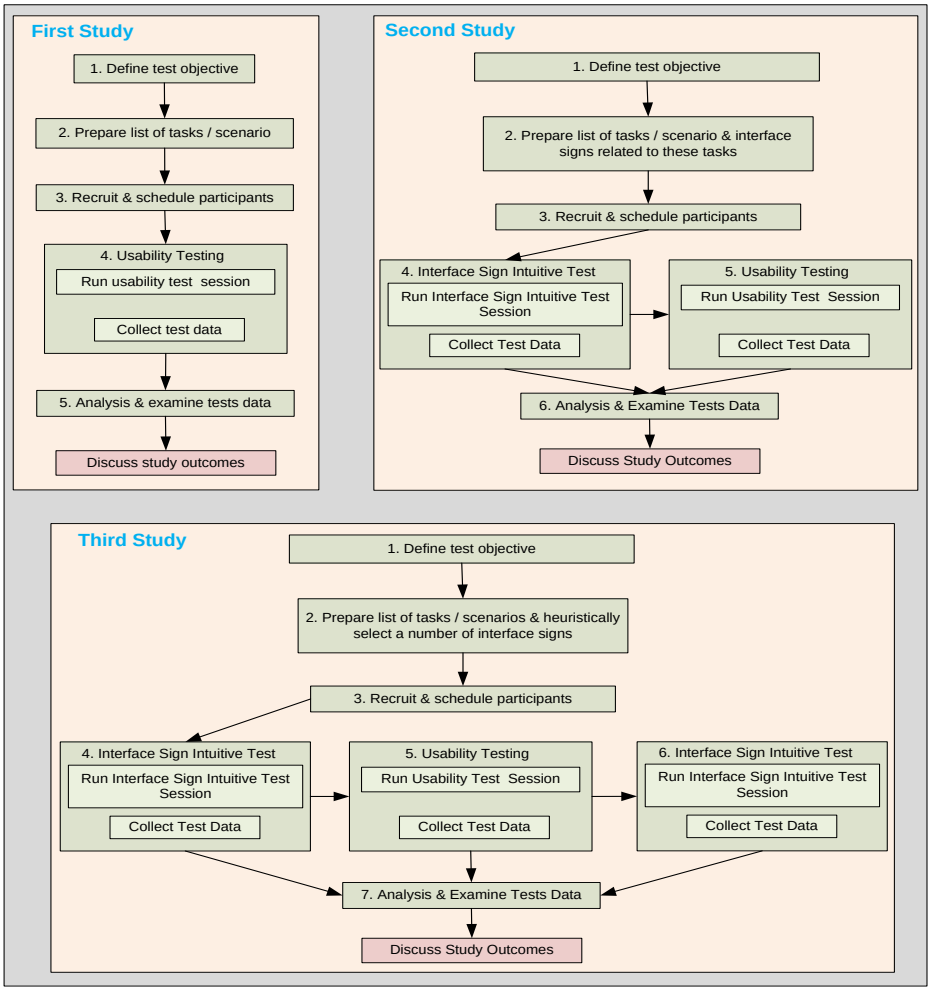


Figure 9. Methodological overview of *Study VI*

Contribution: This study shows the benefits of integrating semiotic concepts in usability testing to find any usability problems and to recommend solutions to these problems. The study also provides procedural guidelines to integrate the semiotic in usability testing. This study contributes to research questions *RQ3 and RQ5*, and the original publication *Paper V*.

3.2.7 Overview of Study VII Design

Study Focus: Assess quality and applicability of the SIDE framework for designing and evaluating interface signs.

Methodological Overview: The study includes two studies – referred to as *Study A* and *Study B*. The *Study A* is carried out with 6 student participants. An interface sign intuitive test (ISIT) is carried out in *Study A* for each participant to test the intuitiveness of a set of interface signs and to identify the problems, i.e., a violation or lack of semiotic design guidelines/heuristics that reduce the intuitiveness of interface signs. The *Study B* was carried out with a total of 17 participants; among them 11 are graduate students who have some experience with UI design and evaluation, and 6 are experts in UI design and evaluation. In this study, the participants are provided with a half-day tutorial to learn and to apply the proposed framework and then are asked to do an assignment (i.e., evaluate the same set of interface signs tested in *Study A* using the SIDE framework); this is followed up by answering a questionnaire related to the proposed framework. Finally, the study measures values of the quality metrics (i.e., thoroughness, validity, effectiveness, efficiency, reliability, learning ability, appropriateness, and accuracy) of the SIDE framework in terms of evaluating the interface signs, and analysis the evaluators' responses to find the important characteristics of the SIDE framework. The results of *Study A* are used as a standard against which to measure the performance metrics of the SIDE framework in terms of evaluating the interface signs.

Data collection and analysis: The study data is collected through semi-structured interviews, problem-solving assignment (expert inspection), and through questionnaires (a biographical questionnaire and questionnaires on the SIDE framework); then the quality metrics are measured and the study data is analyzed using descriptive statistics and a qualitative analysis method.

Contribution: The study results show the quality and applicability of the SIDE framework to designing and evaluating the web interface signs. The study thus contributes to research question RQ5, and to the original publication *Paper VII*.

3.3 Following the DSR Process to Address the Research Questions

The thesis follows the DSR process to address the research questions of this thesis (see figure 10). *Study I* focuses on the groundwork of semiotics in HCI and identifies the research strength, gaps and challenges of semiotics studies for UI design and evaluation. *Study II* is carried out with the objective of understanding the initial benefits of applying semiotics concepts in usability evaluation and interface design. These two studies follow the first two activities (*problem identification and motivation*, and *define objectives of a solution*) of the DSR process and provide responses to the first two (RQ1 and RQ2) research questions.

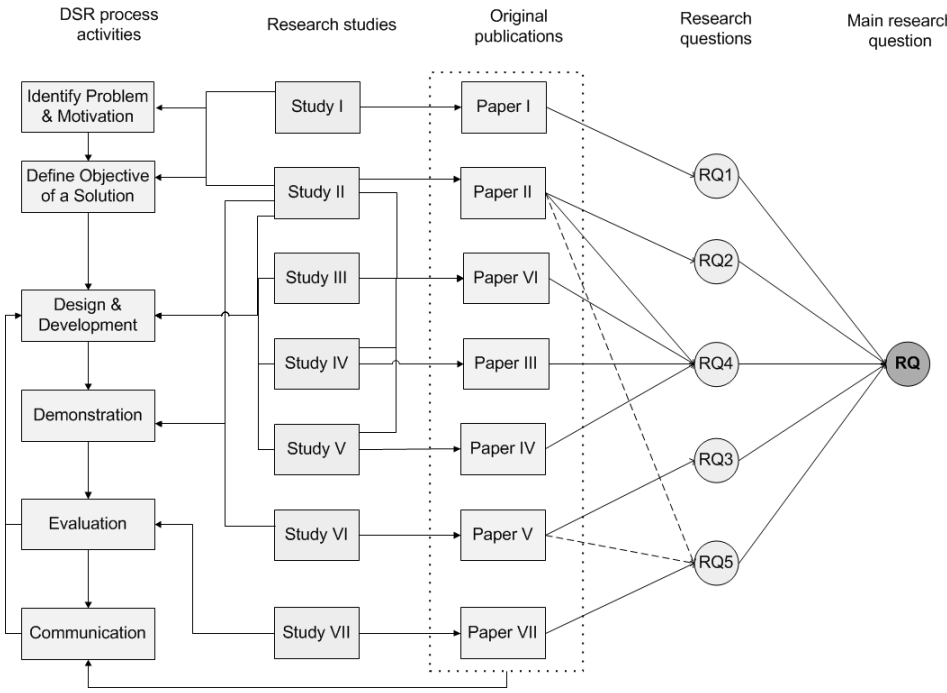


Figure 10. Linkages between the studies, the DSR activities, the original publications, and the research questions

The final artifact, the SIDE framework, is developed by incorporating a number of semiotic features or instruments (determinants, attributes, and design guidelines/heuristics) for user-intuitive interface signs. These semiotic features are developed by a series of empirical studies (*Study II*, *Study III*, *Study IV*, and *Study V*). The usefulness and effectiveness of semiotic features that were

observed preliminary in *Study II (phase I)* are demonstrated in *Study II (phase II)*. In *Study VI*, we demonstrate how integrating semiotic concept can improve system usability. Moreover, the semiotic instruments derived from *Study IV* (carried out by an expert inspection) are further validated by an extensive empirical user study (*Study V*), i.e., the semiotic instruments derived in *Study IV* and also found in *Study V* are used for developing the SIDE framework. These iteratively occurred over a period of 36 months to find the semiotic instruments for user-intuitive interface sign design and evaluation. The preliminary set of semiotic features observed in *Study II*, *Study IV* and *Study V* are published in *Papers II, III* & *IV* respectively. The SIDE framework is published in *Paper VI*. These papers (*Paper II-IV & VI*) contribute to the research question RQ4. The results of *Study VI*, where we assess the value of integrating semiotic concepts in usability evaluation, are published in *Paper V* that contributes to the research question RQ3. Thus, *Studies II-VI* follow the next two activities (*design and development*, and *demonstration*) of the DSR process and provide responses to research questions RQ3 and RQ4; and *Studies II & VI* provide responses partially to research question RQ5.

The SIDE framework is then evaluated to assess its applicability and quality for designing and evaluating user-intuitive web interface signs in *Study VII*. The results of this validation study are also used to refine the SIDE framework. The validation results are published in *Paper VII* and contributed to research question RQ5. *Study VII* thus shows how the research process follows the *evaluation* activity of DSR process. The results are published at different stages of the research progress as shown in figure 10, which represents how the research process follows the *communication* activity of DSR.

Chapter 4

Results

This chapter provides an overview of the original publications by discussing the research questions investigated, the methods used, and the study outcomes. After this, a summary of the results of the whole thesis is discussed. For a more detailed discussion of the results, readers are referred to the publications attached to the end of this dissertation summary.

4.1 A Summary of the Original Publications

Paper I: Islam, M. N. (2013). A Systematic Literature Review of Semiotics Perception in User Interfaces. *Journal of Systems and Information Technology*, Vol. 15 (1), pp. 45-64.

The paper reports the results of a systematic literature review and served as a descriptive background paper for this thesis. This review investigates semiotic studies related to information systems design, development, and evaluation to find the current research strengths, gaps, and challenges. The study investigates the following research questions: "*what kinds of semiotic research have been employed by researchers in user interface design and usability evaluation?"* and *"how are they employed?"* This paper is based on *Study I*. The methodology is discussed more comprehensively in section 3.2.1. As outcomes, the review shows the importance of semiotic studies for user interface design and evaluation, and shows the strengths, gaps, and challenges of semiotic studies for user interface design and evaluation. This review explores the further research possibilities to the research gaps, such as to improve further the value and applicability of research ideas by developing more complete and generalized semiotic guidelines and frameworks for UI design and evaluation. This review further shows that semiotics aspects should be considered in usability evaluation and that more attention be given to validating the study result, to considering cultural issues in semiotics research for culturally adapted user interface design

and evaluation, and to research on mobile apps and mobile web interfaces with semiotic aspects.

Paper II: Islam, M.N., & Tétard, F. (2014). Explore the Impact of Interface Signs' Interpretation Accuracy, Design, and Evaluation on Web Usability: A Semiotics Perspective. *Journal of Systems and Information Technology*, 16 (4).

This paper explores the following two important concerns of web usability: (a) how user-intuitive interface signs affect web usability, and (b) how applying semiotic in user interface design and evaluation helps to improve the system's overall usability. The research question is formulated as *why is considering semiotic perception in user interface design and evaluation so important to improve web usability?* This paper is based on *Study II*. The methodology is discussed more comprehensively in sections 3.2.2. As results, the study shows that (i) users' interpretation accuracy of interface signs affects web usability, i.e., users' inaccurate interpretations of interface signs significantly create web usability problems, and (ii) considering semiotic concepts in user interface design and evaluation is important to improve the overall web usability. Apart from these two concerns, the study provides a small set of semiotic guidelines for interface sign design and evaluation. For example, (i) avoid to use identical signs for multiple purposes; (ii) present clearly the dependency relation among interface signs; and (iii) present clearly the interface sign's interactivity.

Paper III: Islam, M. N. (2012). Semiotics Perception towards Designing Users' Intuitive Web User Interface: A Study on Interface Signs. In H. Rahman, A. Mesquita, I. Ramos, and B. Pernici (Eds.), *Proceedings of the 7th Mediterranean Conference on Information Systems*, Lecture Notes in Business Information Processing , LNBIP Vol. 129, pp. 139-155, Springer-Verlag.

The aim of this paper is to discover semiotic features for user-intuitive interface signs design and evaluation. The research question is formulated as *what semiotic considerations are needed to design users' intuitive web interface signs for improving the web usability?* This paper is based on *Study IV*. The methodology is discussed more comprehensively in section 3.2.4. As outcomes, this study provides a set of semiotic features or considerations for design and evaluation of user-intuitive web interface signs. A set of guidelines is also derived from these semiotic features. For example, avoid designing interface signs that belong to the Website Ontology; change sign labels or texts so that eventually the ontology also changed to represents a lower level of perceived difficulty; create signs that belong to the Internet Ontology and Web Domain Ontology; append small texts or icon or thumbnail with interface signs, where necessary.

Paper IV: Islam, M. N. (2013). Towards Determinants of Designing User-Intuitive Web Interface Signs to Improve Web Usability. In M. Aaron (eds.), *Proceeding of the 15th International Conference on Human-Computer Interaction (HCI International 2013)*, Lecture Notes in Computer Science, LNCS Vol. 8012, pp. 84-93, Springer-Verlag.

The aim of this paper is to find the determinants (themes) of user-intuitive interface signs to improve web usability. The research question formulated is *what are the determinants of user-intuitive user interface signs from a semiotic perspective in order to improve web usability?* This paper is based on *Study V*. The methodology is discussed more comprehensively in section 3.3.5.The paper reports preliminarily results of this study. As outcomes, the study finds a set of determinants (themes) and attributes (sub-themes) for interface sign design and evaluation. For example, the following determinants are found in this study: (i) user's presupposed knowledge, (ii) the interactivity of interface signs, (iii) ontological classification, (iv) amplification features of interfaces signs, (v) interface sign position, (vi) interface sign color, and (vii) matching features of interface sign.

Paper V: Islam, M.N., & Tétard, F. (2013). Integrating Semiotics Perception in Usability Testing to Improve Usability Evaluation. In M. Garcia-Ruiz (Eds.) *Cases on Usability Engineering: Design and Development of Digital Products*, pp. 145-169, USA: IGI Global.

The aims of this paper are (i) to assess the applicability of integrating semiotic concept in usability testing (UT); and (ii) to find the possible benefits of integrating semiotic concept in UT. This paper also presents procedural guidelines for obtaining the perceived benefits of integrating semiotic concept in UT. The fundamental question is *what benefits are observed by integrating the semiotic perception into usability testing?* This paper is based on *Study VI*. The methodology is discussed more comprehensively in section 3.3.6. As outcomes, the study shows that integrating semiotic concepts into usability testing yields the following benefits that contributes to web usability: (i) provides an overall idea of the intuitiveness of interface signs for end users; (ii) contributes to understandability (improving the users' interpretations accuracy) of interface signs; (iii) indicates how learnable the applications are by the real users; (iv) helps to find usability problems and recommend possible solutions; (v) gives background for guidelines to design user-intuitive interface signs; (vi) helps in constructing checklists from a semiotic perspective for heuristic evaluation; (vii) gets the acceptance of customers; and (viii) requires no additional resources. The paper also presents a set of procedural guidelines (i.e., how to design the usability study) to obtain the perceived benefits.

Paper VI: Islam, M.N. (2014). Towards User-Intuitive Web Interface Sign Design and Evaluation: A Semiotic Framework. (*Submitted to International Journal of Human-Computer Studies for peer-review*).

The aims of this paper are (i) to find the underlying features associated with the users' interpretations to get the referential meaning of the interface sign accurately, and (ii) to discover the features to design and evaluate user-intuitive web interface signs in order to improve web usability. The research question addressed is *what semiotic instruments are needed to design user-intuitive user interfaces for improving web usability?* The outcome is based on a series of four empirical studies on web user interfaces. The studies are the *Study II*, *Study III*, *Study IV*, and *Study V*, which are discussed comprehensively in Sections 3.3.2, 3.3.3, 3.3.4, and 3.3.5 respectively. The data is collected by observation in a usability testing lab, by analytical (expert) inspections, and by structured and semi-structured interviewing; data is analyzed through descriptive statistics and qualitative analysis. The determinants and attributes of user-intuitive interface signs, derived from the empirical studies, are triangulated to the semiotic levels to construct a semiotic interface sign design and evaluation (SIDE) framework for web UI design and evaluation (see figure 11).

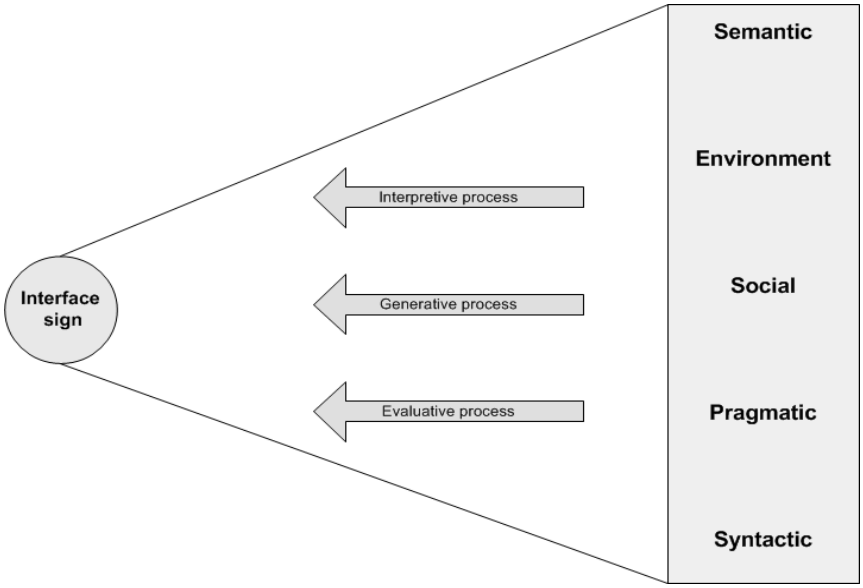


Figure 11. The proposed semiotic framework for UI design and evaluation

The framework includes *(a)* a set of determinants and attributes of interface sign design and evaluation, and *(b)* a set of semiotic heuristics for interface sign design and evaluation. The framework also includes three processes which reflect the end users' interpretation process (interpretative process), the design

process for the interface signs (generative process), and the evaluative process for interface signs (evaluative process).

Paper VII: Islam, M.N., & Bouwman, H. (2014). An Assessment of the Semiotic Interface sign Design and Evaluation (SIDE) Framework. TUCS Technical Report, April, 2014.

The paper presents an assessment of the SIDE framework. The focus is on (a) assessing the quality of the SIDE framework, and (b) understanding the valuable insights and characteristics of the SIDE framework from an evaluator perspective. The research question is formulated as *how applicable is the SIDE framework to designing and evaluating the user-intuitive interface signs?* This paper is based on *Study VII*. The methodology is discussed more comprehensively in section 3.2.7. As outcomes, the study shows that the SIDE framework is applicable to designing and evaluating the interface signs and helps to improve the intuitiveness of interface signs, for example, (a) the study gets quite an acceptable value on quality metrics, (b) the subjective assessments show that all participants are agree with all the statements related to the ease-of-use, contribution, way of using, and the future use of the SIDE framework. The study also reveals the benefits and drawbacks of the SIDE framework from the evaluators' perspective. This result also helps to refine the SIDE framework to reduce the observed drawbacks of the framework.

4.2 A Summary of the Results of the Whole Thesis

This sub-section presents the main results of the thesis and discusses their implications. The results can be summarized as leading to the following contributions; they

a) present the current status of semiotic research in UI design and evaluation.
b) explore the importance of considering semiotic perception in UI design and evaluation.
c) provide a set of ontologies of web interface signs to design and evaluate the interface signs
d) explore the value of integrating semiotic concept in usability testing.
e) propose a semiotic framework.
f) assess the quality and applicability of the proposed semiotic framework.

In the following sub-sections, these contributions are discussed briefly.

4.2.1 Present the current status of semiotic research in UI design and evaluation

A systematic literature review (*Study I*) has been conducted in 2011 that includes relevant papers published from 1986 to July 2011; the results of this study are published in paper I. The recently published (August 2011 to 2013) relevant papers are briefly discussed in section 2.3. A synthesis of the recently published articles combined with the results of *Study I*, gives the following outcomes:

The review shows the semiotic strengths in HCI. For example, (a) semiotic research in UI provides better designs of web applications, improves users' satisfaction, improves the designers-users communication, and contributes to the usability evaluations, mainly for the desktop-based applications or web applications; (b) semiotic also provides support to interface design for human-robot interactions, to the evaluation of multi touch interfaces, and to design and evaluation of mobile interfaces, and mobile games; and (c) semiotic studies increased at a remarkable rate in the last decade.

Study I identifies research strengths, gaps, and challenges. The review (*Study I*) results are summarized below:

- Most of the studies provided conceptual frameworks and developed theories; only a few studies clearly provided guidelines or principles for user interface design and evaluation.
- Most of the results are provided through conceptual methods followed by the empirical research methods.
- A limited number of studies explicitly considered usability evaluations; the mostly used methods for usability evaluation were inspections methods followed by user tests methods.
- Most of the papers explicitly focused on web interfaces.
- There were no studies of mobile web interfaces and only one paper focused on the interfaces of mobile applications.
- A very limited number of papers considered cultural issues.
- A limited number of studies validated the research outcomes; the validation mostly used case studies and experiments.
- The benefits achieved from semiotic research in the user interface were mainly related to information system design and development, to users' satisfaction, to users' task performance, to usability evaluation, and to assessing the communicability of the system. Most of the studies were conducted to obtain benefits related to system design and to the communicability of the system.
- Semiotic research increased at a remarkable rate during the last decade.

Based on the research gaps found in *Study I*, we suggested the following further research possibilities in the field of semiotic research in HCI in 2011:

- *Improve further the value and applicability of research ideas in this environment (i.e., semiotic research in HCI).* Future work in this line can provide more complete and generalized design guidelines and frameworks for user interface design and evaluation.
- *Consider semiotic perception in usability evaluation.* More studies are needed to integrate the semiotic perception in usability evaluation, to explore the value of an integration approach, and to provide methodological guidelines on how to do evaluation studies from a semiotic perspective.
- *Focus more on outcome validation.* Further studies are needed to validate the study results that were not validated before and also for already validated results to make the results appropriate for use by practitioners.
- *Consider cultural issues.* More studies are needed to improve the semiotic concepts, frameworks, and/or guidelines for culturally adapted user interface design and evaluation.
- *Research on mobile apps and mobile web interfaces.* Semiotic studies in this area are at a starting point, so it is still an open problem and can be considered a potential area for future work.

The research for the thesis is carried out by focusing on the first three gaps, and the contributions of the thesis to these research gaps are discussed in section 5.2.

However, the recently published articles (discussed in section 2.3) show that the critical gaps found in 2011 have been reduced to a certain extent by other researchers. For example, (a) two semiotic-based evaluation methods and a set of semiotic guidelines have been proposed for evaluating the web user interface (i.e., Derboven et al., 2013; and Brejcha & Marcus, 2013); (b) two studies are carried out that focus on the issues of usability and user experience considering the semiotic concept (i.e., Tancredi & Torgersson, 2013; and Rousi, 2013); (c) a few studies are carried out to validate and assess the applicability of previously proposed semiotic approaches in UI (e.g., Reis & Prates, 2013: 2012; Derboven et al., 2013; 2012; Tancredi & Torgersson, 2013); (d) a study is carried out that explicitly considers cultural issues in designing for user interfaces (i.e., Cameron et al., 2011); and (e) three semiotic studies are carried out on mobile interfaces (i.e., Valdeshtilhas et al, 2013; Gatsou et al., 2012; and Rousi, 2013)

Thus, the thesis provides an understanding of the current status of semiotic research in UI design and evaluation up to 2013. This result contributes to the study of UI design and evaluation, and suggests actual advances in the state of practice of semiotic studies in user interfaces.

4.2.2 Explore the importance of considering semiotic concept in UI design and evaluation

Semiotic has a significant role in HCI but a limited number of studies had considered the semiotic aspects in UI design and evaluation. A few usability evaluation methods apply semiotic for evaluating the usability of web applications. Moreover, a few studies explicitly focused on 'interface signs' in evaluating web usability though the 'interface sign' is considered to be one of the key dimensions for designing better web user interfaces.

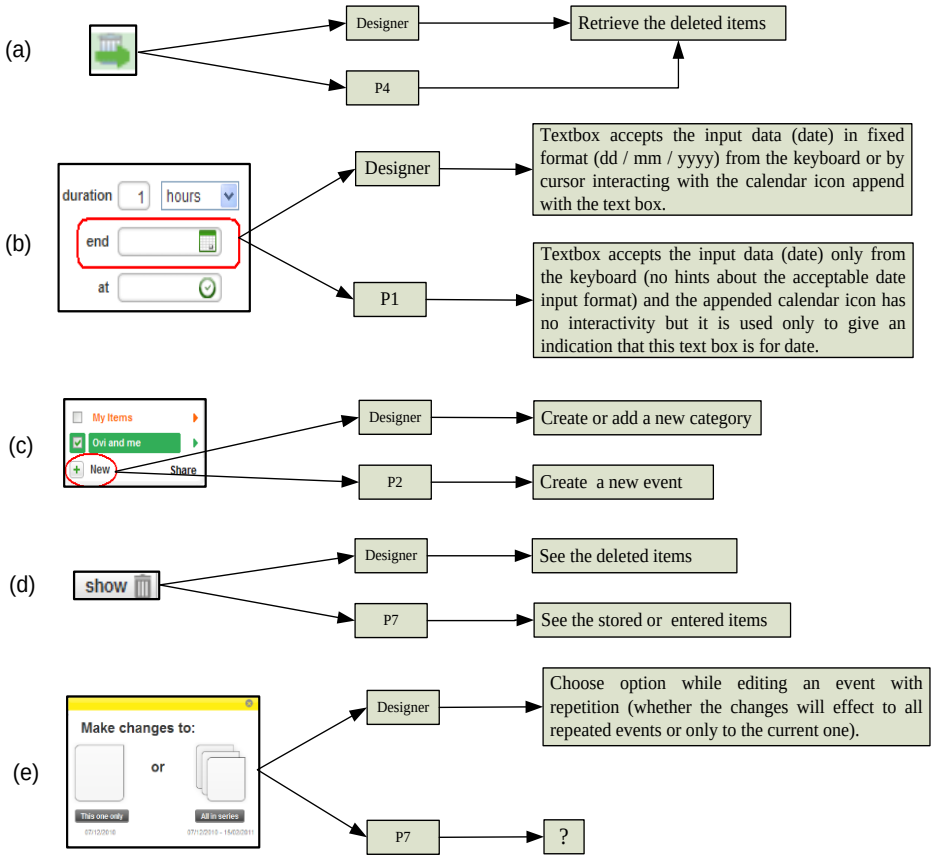


Figure 12. Examples of users' interpretations accuracy to get the meaning of interface signs (a: accurate, b: moderate, c: conflicting, d: erroneous, and e: incapable)

The interface signs need to be intuitive for end users of a usable application and therefore an important part of UI design and evaluation. Thus further empirical study was needed to explore the importance of semiotic in designing interface signs that are intuitive to the end users, and also for improving the system's

usability. An empirical study (*Study II*) is carried out in this thesis to fill this research gap. The study results are summarized as follows:

- Users' interpretations of interface signs vary with respect to the designers' assigned meaning. End-users' interpretations of web interface signs may be *accurate, moderate, conflicting, erroneous,* or *incapable* with respect to the designers' assigned (or intended) meaning. Figure 12 shows a few examples of users' interpretations of interfaces sign to present how users' interpretations are varied with respect to the designers' assigned meaning.
- User-intuitive interface signs lead users to interpret the meaning of the interface signs accurately.
- Users' inaccurate (*moderate, conflicting, erroneous,* or *incapable*) interpretations of interface signs lead to usability problems, and hence lower task performance.
- The accuracy of users' interpretations as well as the intuitiveness of interface signs have increased for a set of interface signs which are re-designed by considering semiotic guidelines (i.e., semiotic perception).

The results show that semiotic concept in UI design and usability evaluation is important as user-intuitive interface signs improve overall system usability. These results are reported in *Paper II*.

4.2.3 Explore interface sign ontologies

Ontologies are important for understanding the meaning of interface signs accurately. This thesis found ontology as a determinant of user-intuitive interface sign and mapped to environment level of the SIDE framework. A proper matching between the ontology/ontologies presupposed by an interface sign and the ones known by a participant helps him/her to interpret the referential meaning of this sign properly. Motivated from Speroni (2006) and Bolchini et al. (2009), the thesis further explores the set of web sign ontology.

The thesis provides a total of twelve ontologies to interpret the meaning of interface signs; six of them have also been proposed by Speroni (2006) and Bolchini et al. (2009). The set of ontologies includes: Internet Ontology, System Ontology, Computer Ontology, Mobile Ontology, Organization Ontology, Real-world Ontology, Cultural Ontology, Website Ontology, Common-sense Ontology, Current Web Domain Ontology, Other Web Domain Ontology, and Topic Ontology. For example, *Current Web Domain Ontology* refers to the knowledge of web interface signs which is specific enough to the current web domain. In *Study V*, the sign 'Junk' is selected from an email application domain. A number of participants understand its meaning properly as they are familiar with email applications. One participant responds *"....I knows this meaning because of my previous knowledge of using email applications...."*

The thesis finds the following features related to ontology mapping in interpreting the meaning of interface signs.

a) Ontology derived from the users' perspective implies that it is referred to by the interface signs.
b) An interface sign may belong to a single ontology or multiple ontologies. Similarly, participants use single or multiple ontologies to interpret the meaning of the interface sign;
c) When ontology that is referred to by an interface sign (from the designer's perspective) differed from the ontology use by the end user to interpret the meaning of the interface sign, then an ontology conflict occur which increases the perceived interpretation complexity and decreases the accuracy of the interpretations.
d) In some other cases, participants are not familiar with all the ontologies referred to by an interface sign. In such cases, participants interpret the meaning of the sign only for ontology/ontologies with which they are familiar.
e) The difficulty experiences to interpret the meaning of interface signs by an individual depends on his or her familiarity with the ontology / ontologies assume for the interface sign.
f) Participants who have heterogeneous profiles experience, (i) a higher level of perceive difficulty with signs that belong to *Website Ontology*; (ii) an average level of perceive difficulty with signs that belong to *System Ontology*, *Other Web Domain Ontology*, *Real World Ontology*, *Organizational Ontology*, *Cultural Ontology*, and *Topic Ontology;* and (iii) a lower level of perceive difficulty with signs that belong to *Internet Ontology*, *Current Web Domain Ontology*, *Computer Ontology*, *Mobile Ontology*, and *Common-Sense Ontology* to interpret the meaning of interface signs properly.

The results also provide a set of guidelines for interface sign design and evaluation, such as (i) design interface signs based on users' familiarity level with ontologies; (ii) create interface signs to avoid ontology conflict; (iii) design interface signs that belong to multiple ontologies; (iv) avoid to create interface signs which belong only to the 'Website Ontology', and (v) design interface signs which belong to ontologies with which users experience a lower level of perceived difficulty (e.g., Internet Ontology).

The results of exploring interface sign ontologies thus assist practitioners to model the users' presupposed knowledge, and to follow semiotic guidelines for interface sign design and evaluation, which in turn helps to design and evaluate the interface signs more completely and in a more meaningful fashion. These results are reported in *Paper VI.*

4.2.4. Explore the value of integrating semiotic concept in usability testing

The thesis assesses the value of integrating semiotic concept in usability testing in *Study VI* and finds the following benefits to contribute to the usability of web applications:

- *To provide an overall idea of how intuitive interface signs are for end users.* Users interpret the interface signs to interact with web systems. Thus understanding the intuitiveness of interface signs helps to assess the usability of a web application. The study (*Study VI)* shows that the integration of semiotic concept in UT (i.e., by interface sign intuitiveness tests) gives an idea of how intuitive interface signs are to end users. This result gives a number of observations to understand the system's usability standard, e.g., what percentage of signs of the studied applications are correctly interpreted by the test-participants; how many signs create confusion in interpreting the referential meaning; etc.
- *To convey the understandability of interface signs and to indicate how learnable the applications are by the end users.* User interfaces build on a number of interface signs, which serve as a means for the users' interaction and communication with web applications. It is important to understand the meaning of interface signs in order to understand the logic of the system, to learn the application, and to get a satisfactory user experience (Salgado et at., 2009; De Souza et al., 2006; De Souza and Cypher, 2008). Thus, a proper understanding of interface signs provides an indication of a system's learnability. The studies showed that the integration of semiotic concept in UT improves understandability of interface signs, and gives an indication of the systems' learnability.
- *To help to find usability problems and to recommend possible solutions.* Finding usability problems is one of the central goals of every usability evaluation method. In some cases the evaluators may fail to identify the main reasons for a particular usability problem. Consequently, their recommendation does not focus on the specific point that creates the problem. Integrating semiotic concept in UT shows the possibility to support the identification and understanding of the actual reasons of usability problems and to recommend possible solutions to these problems. For example, in UT when a participant have a usability problem (e.g., creating a navigational error, staying a longer time in the wrong navigation state, etc.) then his/her interpretation accuracy of the task-related interface signs are reviewed to investigate or analyze the reasons of the usability problem; if the usability problem is due to the user's inaccurate interpretations of a task-related interface sign, then it is recommended to redesign the interface sign.
- *To give background for introducing guidelines to design user-intuitive interface signs and to help with constructing checklists from a semiotic*

perspective for heuristic evaluation. A number of guidelines and/or principles for user interface design and evaluation have been identified to enhance usability of a system in order to improve the user performance, which is the ultimate purpose of a computer application (Mayhew, 1992; Ford & Gelderblom, 2003). Most of the guidelines and/or principles are focused mainly on navigational issues, contents, information architectures, graphics or the layout of user interfaces. Unfortunately a very limited number of guidelines are available for designing user-intuitive interface signs. The study shows that the integration of semiotic concept in UT provides background to introduce guidelines and heuristic checklists for interface sign design and evaluations, e.g., a semiotic guideline derived from *Study VI* is 'present clearly the dependency relation (if present) among interface signs'; this guideline can also be presented as a checklist for heuristic evaluation as 'are the dependency relations among interfaces signs present clearly?'.

- *To receive customers' acceptance of the integration of semiotic in UT.* Getting positive feedback from the customers or developers is expected to motivate usability practitioners, to understand the customer satisfaction with their evaluation results, and also to support the method employed in UT. One experiment in *Study VI* is carried out with real customers and the study received the customers' acceptance for the testing method (i.e., integrating semiotic in UT) and for the report of the usability evaluation.
- *No additional resources or extra funds required.* It is a challenge to carry out an integrated usability testing without asking for any additional budget or resources for usability professionals and customers. The study shows that the integration of semiotic in UT does not need additional resources or extra budget.

4.2.5 Propose a semiotic framework

The thesis proposes a semiotic framework (Semiotic Interface sign Design and Evaluation -SIDE) for user-intuitive interface sign design and evaluation. The SIDE framework includes (a) a set of determinants (themes) and attributes (sub-themes) of interface sign design and evaluation, and (b) a set of semiotic heuristics for interface sign design and evaluation. The proposed framework encompasses the following five semiotic levels (see the figure 11 & 13):

(i) Syntactic - the representational features of interface signs.
(ii) Pragmatic - the relation of interface signs with their interpretation or uses.
(iii) Social - the relation of interface signs with their meaning with respect to their social consequences.
(iv) Environment - the users' presupposed knowledge or ontology to interpret the meaning of interface signs.
(v) Semantic - the referential meaning of interface signs.

Each level subsequently defines determinants and the determinants have attribute(s); for example, interactivity, color, clarity and readability, presentation, context, and consistency are the determinants of syntactic level; sign color, color lightness, and color contrast are the attributes of color (a determinant) (see the figure 13). The framework also includes three processes:

(i) Interpretative process - the process of interpretation of interface signs to get their referential meaning.
(ii) Generative process - the process of designing the interface sign that encodes the referential content or meaning as an 'interface sign'.
(iii) Evaluative processes - the process of investigating or analysing interface signs (a) to assess the intuitiveness for the end users, (b) to find the design problems, and (c) to recommend possible design solutions to improve the intuitiveness.

The studies mainly focus on the interpretative process and derive a set of determinants and attributes of interface signs that are associated with users' interpretations. The ways practitioners can use determinants and attributes for designing and evaluating interface signs are conceptualized as the generative and evaluative processes respectively; hence a set of semiotic heuristics is proposed for each level of the framework. The semiotic level, determinants, and attributes of the proposed framework are showed in Figure 13. A summary of determinants and attributes derived from different studies is presented in Table 5. Table 6 presents the condensed set of proposed heuristics for different semiotic levels. Next the determinants and attributes are presented briefly. The results are mainly reported in *Paper VI.*

The Syntactic Level: This level comprises the features of interface sign presentation. The following determinants of the syntactic level are derived:

- Interactivity – Interface signs carry six kinds of proposed interactivity: *decorative (*not clickable and uses mainly for a decorative or aesthetic purpose*); indicative (*not clickable and provides suggestions or hints in the UI*); indicative-interactive (*one can interact with this kind of sign only for understanding some indication or hints, not for performing a task*); functional (*clickable and performs a task*)*; *navigational, (*clickable and goes through to further details of information*),* and *hybrid-interactive (*combines the properties of other attributes of interactivity, e.g., combines the *indicative-interactive, functional*, and *navigational* attributes*).*
- Color – This determinant is concerned with the color used (*sign color*), the *lightness* of the color, and the *contrast* of the color.

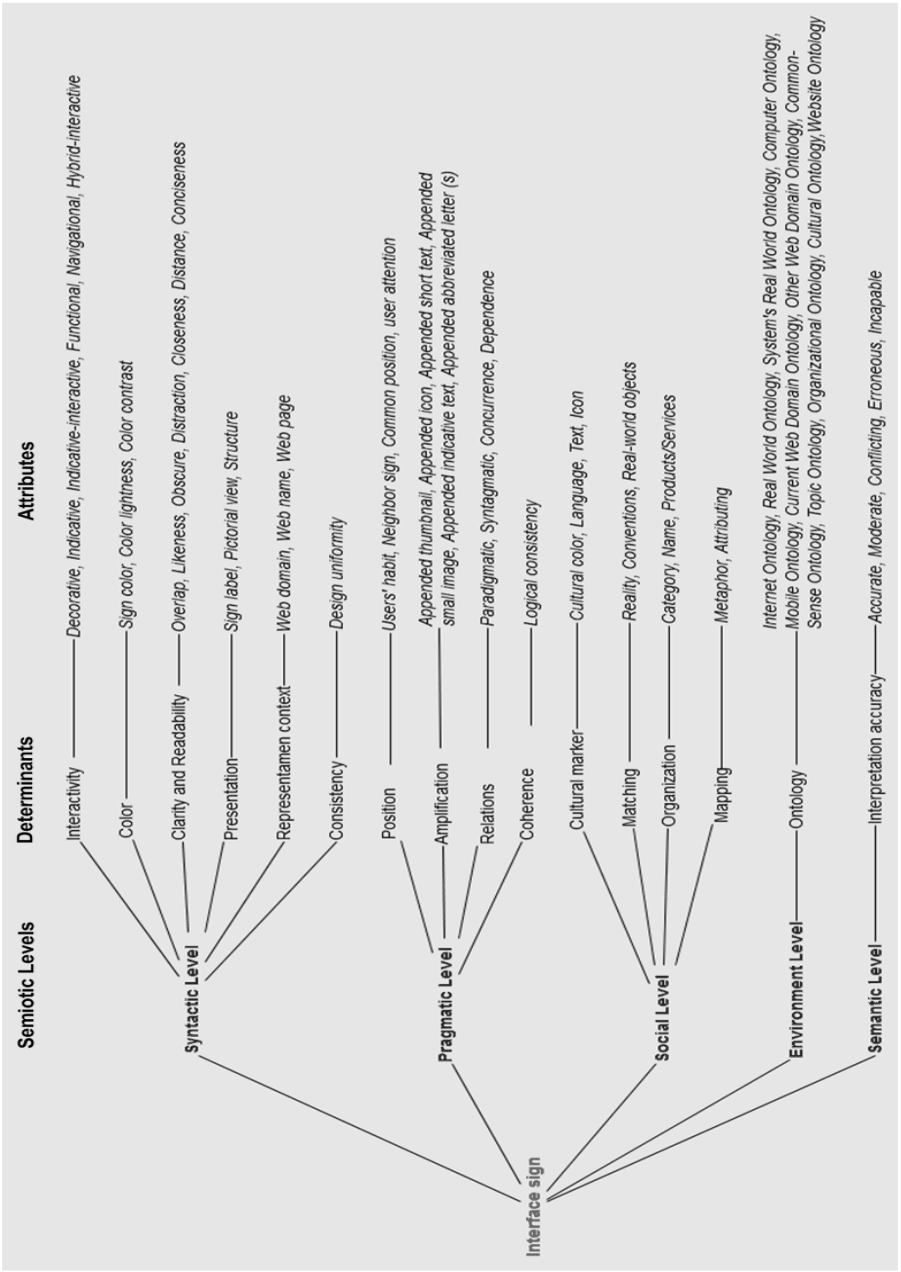


Figure 13. The SIDE framework: levels, determinants, and attributes

- Clarity and readability – This determinant does not directly impact the participants' interpretations of interface signs, but indirectly helps to interpret them appropriately. This determinant includes the following attributes: (i) *overlap (*the sign's texts that are merged by overlapping a few letters*)*; (ii) *likeness (*the signs' labels that are too similar to other signs*)*; (iii) *obscure (*signs that are unclear, hidden, and difficult to understand*)*; (iv) *distract (*signs that might be properly understandable by the end user, but are less important than what their appearance make out to be*)*; (v) *closeness (*signs that are placed too close to another sign*)*; (vi) *distance* (refers to the use of noticeable distance between related interface signs), and (vii) *conciseness (*the use of short and effective text as a sign label*)*.
- Presentational aspects – The presentational aspects of an interface sign on the syntactic level is concerned with the *labels* of the interface sign, what the sign looks like (*pictorial view*), and the *structure* of the interface sign such as the layout, shape, size, font size, etc.

Table 5. Determinants derived from different studies

Level	**Determinants**	**Study II**	**Study III**	**Study IV**	**Study V**
Syntactic	*Interactivity*	X	X	X	X
	Color	X	X	X	X
	Clarity and readability				X
	Presentation	X	X	X	X
	context	X	X		X
	Consistency	X			X
Pragmatic	*Position*	X	X		X
	Amplification	X	X	X	X
	Relations	X			X
	Coherence				X
Social	*Cultural marker*		X	X	X
	Matching		X		X
	Organization	X	X		X
	Mapping	X	X	X	X
Environment	*Ontology*	X	X	X	X
Semantic	*Interpretation accuracy*	X	X	X	X

- Context – This determinant on the syntactic level is concerned with the name of the web domain, the name of the website or web application (*web name*), and the *webpage* that holds the interface sign
- Consistency – This determinant is concerned with consistent design (*design uniformity*) that should be followed when designing interface signs for a particular web application. The uniform design strategy for a website helped participants to develop their thinking process to interpret the meaning of the interface sign.

Table 6. Proposed semiotic heuristics (only the condensed set of heuristics are presented here, full set of heuristics are available in *Paper VI*)

Levels	Semiotic Heuristics
Syntactic	- Present clearly the purpose of interactivity - Make effective use of color to design an interface sign - Make the representamen readable and clearly noticeable - Make a sign presentation clear and concise - Create the representamen context appropriately - Follow a consistent interface sign design strategy
Pragmatic	- Place the interface sign at the proper position in a UI - Make effective use of amplification features in interface sign design - Create good relations among the interface signs of a UI - Retain logical coherence in interface sign design
Social	- Design interface signs to be culturally sensitive or reactive, when necessary - Match with the reality, conventions, or real-world objects - Make effective use of organizational features in interface sign design - Map with metaphorical and attributing properties
Environment	- Model the profiles of the focused end-users - Make effective use of ontological guidelines in interface sign design
Semantic	- Design an interface sign to get its accurate meaning by the end users

The Pragmatic Level: The pragmatic level deals with the relation of interface signs to their interpretation or use. The following determinants of the syntactic level are derived:

- Position – Interface sign location on the pragmatic level is concerned with three main attributes: *users' habits (*refers to how users interact with

interface signs at a particular position in an UI*), neighbor signs (*refer to the surrounding or close by signs*), user attention* (refers to placing an interface sign at a particular position in a UI to get users attention) and *common positions (*refers to particular positions for interface signs*).*

- Amplification – This determinant on the pragmatic level is concerned with the following attributes: *appended thumbnail* (meaningful thumbnail appended with an interface sign), *appended icon* (meaningful icon appended with an interface sign), *appended small image* (meaningful small images appended with an interface sign), *appended short text* (short text appended with an interface sign that provides hints for the meaning of the sign), *appended indicative text* (meaningful small text appended with an iconic interface sign), and *appended abbreviated letter(s)* (common abbreviated letter(s) appended with a linguistic sign, e.g., 'e' for electronic, 'I' for internet, 'web' for internet or online, etc.). These attributes are individually not enough to express the meaning of an interface sign properly, but they impact the perceived meaning, complexity, and confidence when appended with other interface signs.
- Relations – The relations on the pragmatic level refer to the associations between interface signs in a UI. This determinant concerned four types of relations: (i) *paradigmatic (*relations that hold among interface signs of the same paradigm*)*; (ii) *syntagmatic* (refers to a relation among interface signs that makes a sequential order within the signs or combines them with a sequential order*); (iii) concurrence (*a few thematic or functional relations exist together among the interface signs in a UI*);* and (iv) *dependence (*the meaning of the interface sign depends on another sign or is controlled by another sign in a UI*).*
- Coherence – This determinant is concerned with the quality of being logical in interface sign design (*logical consistency*). The *logical consistency* refers to how well the meaning of the interface sign is logically related with real-world facts.

The Social Level: The social level deals with the meaning of the interface sign in terms of its social consequences. The following determinants of the syntactic level are derived:

- Cultural marker – The cultural marker on the social level is concerned with the sign *color* and its cultural consequences, the *language* of the sign label, the *text* of the sign and its cultural consequences, and the *iconic* interfaces for a particular cultural context.
- Matching – This determinant is concerned with *reality* (the interface sign represents or follows some underlying reality), *conventions* (the sign is designed following the conventions of interface signs), and *real-world objects* (the interface sign corresponds or matches with a real-world object).

- Organization – This determinant refers to the owner or interlocutor of a website that is concerned with an organization's *category*, an organization's *name*, and an organization's *products or services*.
- Mapping – This determinant is concerned with *metaphors* that resemble users' real-world experiences more realistically in order to enhance interpretation accuracy, and *attributing* that refers to the use of parts in interface sign design; participants interpreted the meaning of the (whole) interface sign properly when they determined its parts and understood the meaning of the parts.

The Environment Level: The environment level deals with the environmental or surrounding factors that are collectively capable of affecting the users' behavior. The level builds on the users' *presupposed knowledge* or *ontology*. The environment level represents, (i) the users' knowledge and memory, and (ii) an association of users' interpretations of interface signs with the referential meanings of the signs, because the users' memory and knowledge form the basis to understand the meaning of a sign in a semiosis process. The determinant 'ontology' for this level is derived.

- Ontology–The term 'ontology' is defined as the set of concepts and skills that a user should have to understand the referential meaning of an interface sign (Bolchini et al. 2009; Speroni 2006). Thus the ontology is important for interpreting the meaning of a sign accurately. The studies found a set of ontologies to interpret the meaning of the interface signs (see section 4.2.3), for example, *Internet Ontology* (concept related to the web, web surfing, world of web, etc., e.g., the 'Logout' sign), *Current Web Domain Ontology* (the knowledge of web interface signs which is specific enough for the current web domain, e.g., the 'Spam' sign in the email application domain).

The Semantic Level: The semantic level is the meaning of the sign and the relationships of (i) the interface sign, (ii) the referential meaning of interface signs from a designer perspective, and (iii) the referential meaning of interface signs from a user perspective. The determinant that is derived for this level is the 'interpretation accuracy'.

- Interpretation Accuracy – This determinant refers to the accuracy level of users' interpretations of interface signs with respect to the designers' intended or assigned meaning of the signs. The accuracy level of users' interpretations of interface signs falls into five categories (see the figure 12): *accurate* (a user's interpretation completely matches the designer's assigned meaning); *moderate* (the user interprets more than one distinct meaning or object, one of which was the correct one and the probability to obtain the right object at the first attempt may be less than for the accurate interpretation); *conflicting* (the user interprets more than one distinct object from the interface signs and is confused about choosing the right object that

will match the designer's assigned meaning or object); *erroneous* (a user's interpretation matches a completely different object than the designer's assigned meaning); and *incapable* (the user was not able to interpret the interface sign at all).

4.2.6 Assess the quality and applicability of the SIDE framework

The thesis evaluates the quality and applicability of the proposed semiotic framework in *Study VII*. These results are reported in *Paper VII.* The study results are summarized as follows.

a) Assessing the quality metrics: The results with regard to the performance metrics are quite acceptable. For example, novice evaluators spend about 4-6 hours to learn the SIDE framework and are still able to detect about 67% problems accurately; for intermediate evaluators *thoroughness*, *validity*, and *appropriateness* are 0.78 (0.10), 0.80 (0.14), and 70%, respectively.

b) Assessment of the close-ended questions: All participants are agreed with all the statements related to the ease-of-use, contribution, way of using the framework, and the future use of the SIDE framework. Novice and intermediate evaluators have some difficultly to understand and use the framework. A comparatively higher score is given for the statements related to the themes of contribution of the framework and the way of using the framework. The results also show that experts to a large extent agree with all the statements.

c) Assessment of the open-ended questions: The results reveal the benefits and drawbacks of the SIDE framework. The benefits include: (i) the broadness of the framework, (ii) the framework is a useful tool to support the effective design and evaluation of interface signs, (iii) the framework is structured, properly documented and through, (iv) the framework is easy to understand, (v) the framework is grounded in the theories of semiotic, and (v) the framework is valuable and recommended. For example, one expert having 20 years of experiences in UI evaluation, responds: *"…Well, it is the best heuristics for evaluating interface signs that I have seen….It is actually also the only one that I have seen. The points seem relevant to me, but I have not tried to apply them yet….."* The drawbacks include: (i) unfamiliar terminologies are used in the SIDE framework, (ii) insufficient learning resources are provided to understand and apply the SIDE framework, (iii) hierarchical depth of the SIDE framework is complex and sometime confusing, (iv) the framework includes too many features, (v) the framework is too structured and prescriptive to use, and (vi) the framework takes a lot of time and effort to learn and apply in real cases. For example, one intermediate evaluator responds: *"…It takes quite a lot of time to learn*

the framework by heart. I had to look up every single heuristic every time for every sign at every level of evaluation…."

The main drawback of the SIDE framework is that it costs a lot of time and effort to learn to use the framework in evaluating interface signs, because (i) the framework is based on the semiotic concepts and includes a large number of features from a semiotic perspective; (ii) provides limited learning resources; and (iii) follows an approach that is too structured. In addition, the knowledge and skills needed to learn a semiotic-based framework and to carry out any usability inspection can be a good reason that may demand a lot of time and effort; the participants are not familiar with the concept of semiotic, and the evaluators are students having little experience with interface design and usability evaluation.

The main benefit as mentioned by the participants is that the SIDE framework is detailed and covers every aspect needed to design and evaluate the interface signs to make them intuitive for end-users. The framework provides sufficient details to gain an underlying knowledge or concepts to assess intuitiveness of interface signs, to detect the problems of interface signs, and to design/redesign the interface signs to make them more intuitive for end-users in order to improve web usability.

There is no definite way to use the SIDE framework for designing and evaluating the web user interfaces. The way the SIDE framework can be used to design and evaluate the user interfaces is depend on several factors, such as the studied application, the evaluators' expertise on semiotic instruments, the project time, the aims of the interface design and evaluation, the budget, and the methodology followed to design or evaluate the user interfaces. However, the thesis does not provide any definite procedure for using semiotic means for UI design and evaluation; rather, the thesis proposes some example procedures and demonstrates one procedure of using semiotic means for UI design and evaluation in *Study VII*. The thesis proposed the following procedures of using the SIDE framework for UI design and evaluation:

a) As a high-level concept that practitioners keep in mind while designing or evaluating web interfaces.
b) As a standalone tool to recommend possible design solutions or guidelines for interface sign design.
c) As a standalone tool for interface sign evaluation.
d) As a tool integrated with other usability evaluation methods (e.g., lab based usability testing) for UI design and evaluation.
e) As a tool integrated with heuristics (e.g., Nielsen's set of heuristics) for UI design and evaluation.

Table 7. Procedural guidelines to evaluate interface signs

1. Understand the application and model the profiles of end-users
   - Understand the application: the domain, name, purpose and functionality of the application (i.e., what do they want to communicate or provide?).
   - Model the profiles of the focused end-users based on their familiarity with ontologies.

2. Evaluate or investigate the selected interface sign
   Step 2.1: Understand the referential meaning of the selected interface sign.
   Step 2.2: Analyze or evaluate the selected interface sign. (What properties of the signs are used? What properties are missing?)
   Step 2.3: Give the intuitiveness score (1-9; 1: less intuitive, 9: highly intuitive), How accurately can the user interpret the sign? How complicated or difficult is it for the users to interpret this sign? How certain or confident are the users in their interpretation? How transparent is the sign in terms of its actual content/meaning?
   Step 2.4: Recommend possible design solutions, where necessary, to improve the intuitiveness of the sign. (How can the sign be made more intuitive to end-user? What properties of the signs can be used to improve the intuitiveness of the sign?)

Task 1 needs to be carried out once for each application, while task 2 needs to be carried out repeatedly for each sign selected for evaluation.

The thesis collects the evaluators' opinion for all the proposed procedures (in *Study VII*). The results show that evaluators are quite agreeing with all these procedures of using the SIDE framework for UI design and evaluation. For example, *experts* participants in *Study VII* to a large extent agree with all the statements related to these proposed procedures; their mean score to these statements is 4.21 and std. score is 0.82 (in a rating scale of 1 (strongly disagree) to 5 (strongly agree)). Moreover, in *Study VII*, participants are asked to evaluate a set of interface signs using the SIDE framework, and to follow an evaluation procedure. The procedure is presented briefly in table 7. Participants evaluated the given set of interface signs successfully with the SIDE framework as a standalone tool and following the proposed procedure. This study shows that semiotic framework can be used as standalone tools in practice, i.e., the study demonstrates the procedure *c*.

To conclude, the findings show that the SIDE framework is applicable for designing and evaluating the web interface signs and making them intuitive for end-users. Based on our findings, the SIDE framework has already been refined by considering the following activities to reduce the observed drawbacks to a

certain extent: providing understandable terminologies and more suitable examples to explain the attributes of the framework, using a less structured approach to carry out the evaluation process, renaming some determinants and attributes, and refining the categorization of determinants and attributes in the SIDE framework.

Chapter 5

Discussion and Conclusions

This chapter presents the concluding remarks of the thesis. First, a summary of the answers to the research questions is provided. Next, the research contributions are discussed, and then the practical implications of the research are presented. Finally, the limitations of the research and some future research directions are presented.

5.1 Answers to the Research Questions

The results of the thesis are discussed in chapter 4. This section provides a summary of the answers to the research questions (mentioned in section 1.3), and refers to the sections where the results are discussed more comprehensively. The main research question is formulated as follows: *What do practitioners and researchers need to be aware of from a semiotic perspective when designing or evaluating web user interfaces to improve web usability?* The objective is to provide valuable insights to design and to evaluate web user interfaces to find ways to improve system usability from a semiotic perspective. In order to achieve that, five sub-questions are formulated.

The first sub-question is: *What kinds of semiotic research have been employed in UI design and evaluation, and how are they employed?* A systematic literature review (*Study I*) is carried out in order to address this question. Moreover, the research also reviewed a set of articles that are published during the period August 2011- 2013. The thesis summarizes the current status of semiotic research in UI design and evaluation including the research strengths, gaps, and further research possibilities in UI design and evaluation from a semiotic perspective. The results are discussed in section 4.2.1 and in *Paper I*.

The second sub-question is: *Why is considering semiotic concept in user interface design and evaluation so important to improve web usability?* An empirical study (*Study II*) is carried out to address this question. The results show that users interpret the meaning of interface signs accurately when the

signs are intuitive for them; users perform tasks with good performance when their interpretation accuracy of task-related signs is accurate; users' interpretation accuracy of interface signs impacts the overall web usability, and semiotic has a significant role in the design and evaluation of web interface signs to make them intuitive for end users. The result is discussed in section 4.2.2 and in *Paper II*.

The third sub-question is: *What benefits are observed by integrating semiotic concepts into usability testing?* An empirical study (*Study VI*) is carried out to address this question. The study shows that integrating semiotic concepts into usability testing yields a number of benefits that contribute to usability: for example, by providing the intuitiveness of interface signs for end users. The result also presents a set of procedural guidelines to obtain the perceived benefits. The result is discussed in sections 4.2.4 and in *Paper V*.

The fourth sub-question is: *What semiotic instruments are needed to design user-intuitive web user interfaces to improve web usability?* A total of four empirical studies (*Study II - V*) are carried out to address this question. The studies provide a number of semiotic instruments (i.e., determinants, attributes, and semiotic heuristics) for designing and evaluating interface signs to make them intuitive for end-users. The semiotic instruments are triangulated into five semiotic levels to develop the SIDE framework. The result is discussed in sections 4.2.3. and 4.2.5, in *Papers II – IV,* and in *Paper VI*.

The fifth and final sub-question is: *How applicable are the proposed semiotic instruments to design and evaluate web user interfaces?* Three empirical studies (*Phase II* of *Study II*, *Study VI* and *Study VII*) are carried out to address this question. The semiotic instruments, identified preliminarily from *Study II* (*Phase I*) are evaluated in *Study II (Phase II)* to show the effectiveness and usefulness of the semiotic instruments for designing and evaluating interface signs. *Study VI* explores the benefits of integrating semiotic concepts in usability testing. The SIDE framework is evaluated in *Study VII* to assess its quality and applicability for designing and evaluating web interface signs. The study results show that the SIDE framework is applicable to designing and evaluating interface signs and helps improve the intuitiveness of interface signs. These studies (*Study II, Study VI* and *Study VII*) also provide the (procedural or methodological) guidelines for applying semiotic instruments in the design and evaluation of web interface signs. The results are discussed in sections 4.2.2, 4.2.4, 4.2.6, and in *Paper II, Paper V,* and *Paper VII*.

Addressing the five sub-questions constitute the groundwork for answering the main research question: *What do practitioners and researchers need to be aware of from a semiotic perspective when designing or evaluating web user interfaces to improve web usability?* In summary, the results of the thesis are provided in

response to the overall research question and include the following. First, a state of the art of semiotic research in HCI is provided. Second, the importance of considering semiotic concept in UI design and evaluation is shown. Third, a set of ontologies to interpret the meaning of interface signs and a set of features related to ontology mapping in interpreting the meaning of interface signs are provided. Fourth, a number of semiotic instruments for user-intuitive interface sign design and evaluation is provided. Fifth, the benefits of integrating semiotic concepts in usability testing are explored. Sixth, the SIDE framework for interface sign design and evaluation to improve web usability is developed. Finally, the effectiveness and usefulness of semiotic instruments, as well as the quality and applicability of the SIDE framework are evaluated. The results are discussed in section 4.2 and in *Papers I-VII*.

5.2 Research Contributions

The results of the thesis provide valuable insights for designing and evaluating interface signs in order to improve web usability. The research gaps, found in the systematic review study (*Study I*), suggested further research possibilities in the following areas, to: (i) provide more complete and generalized semiotic guidelines and frameworks, (ii) consider semiotic concepts in usability evaluation, (iii) focus more on validating the outcomes of semiotic studies in UI, (iv) consider cultural issues, and (v) carry out research on mobile interfaces. The thesis is carried out to address the first three issues to reduce the research gaps to a certain extent. Table 8 briefly discusses how the thesis results address these issues effectively and provide valuable insights for designing interface signs that are intuitive for end users.

Table 8: Summary of the research contributions

Research Gaps	Contributions
Providing more complete and generalized semiotic guidelines and framework	- The thesis provides a number of semiotic instruments (i.e., derived a total of 16 determinants, 67 attributes, and a set of semiotic heuristics related to the derived determinants and attributes) - The semiotic instruments are derived from empirical data. - A total of 616 interface signs are tested and/or investigated in this thesis. These signs are retrieved from different kinds of web interfaces (e.g., UI of online calendars, online e-health applications, email applications, museum websites, and university websites). - The thesis develops the SIDE framework by

	triangulating the derived semiotic instruments into five semiotic levels. - The thesis validates semiotic instruments and the framework through empirical studies. The thesis finds out in comparisons with related work that the proposed semiotic guidelines and framework are more general and complete for designing and evaluating web interface signs.
Applying semiotic concept in usability evaluation	- The thesis gives an overview of the current status of semiotic research in UI design and evaluation (in *Study I* and in section 2.3, and 4.2.1) - The thesis shows the importance of considering semiotic in designing and evaluating interface signs (in *Study II*). - The thesis shows that semiotic can be integrated into usability testing in order to improve system usability (in *Study VI*). - 'Knowing the users in focus' is a fundamental concern in usability evaluation. Motivated by Speroni (2006), the thesis explores interface sign ontologies that assist in modeling the profiles of the users in focus; which in turn supports the evaluation of interface signs. - The thesis shows that the derived semiotic instruments and SIDE framework can be used as a tool to design user-intuitive interface signs in order to improve overall web usability (in *Study II, VI, & VII*). In sum, the thesis highlights the importance of considering semiotic concepts in usability evaluation and explicitly shows how usability evaluation (both the user test and expert inspection) can be carried out by considering semiotic concepts (e.g., considering the semiotic guidelines, SIDE framework).
Validating the study outcomes	- A set of semiotic instruments are validated through an empirical study (*Phase II* of *Study II*). - The SIDE framework is used by the evaluators (test-participants) to carry out an expert inspection. The results with the performance metrics show that the SIDE framework is quite useful and effective to design and evaluate interface signs (in *Study VII*). - The SIDE framework is communicated to usability experts to get their subjective feedback (in *Study VII*). - The outcomes of the validation study (*Study VII*) are

	used to refine and update the SIDE framework. In sum, the iterative approach used in this thesis to find the semiotic instruments and to develop the SIDE framework makes it clear that the thesis explicitly focused on validating the outcomes. Thus, the results of the thesis are properly validated to assess their quality and applicability for designing and evaluating interface signs.

Moreover, it is very legitimate to raise questions whenever a new semiotic framework or a set of semiotic instruments is proposed, since a few semiotic frameworks, analysis methods, and a number of heuristics or guidelines for UI design and evaluation exist in literature. These questions include 'What is different about it? How can this be differentiated from other related research results? What additional contribution does it make? The results of this thesis can be claimed to be valuable in the following ways.

The results (semiotic instruments and SIDE framework) are closely related to the Semiotic Inspection Method (SIM). The SIM is developed to assess the communicability of computer based interactive applications (De Souza et al., 2006; Reis & Prates, 2013). The SIM puts a significant emphasis on interface signs to assess the communicability of a computer system. The results of the thesis thus extend SIM at least in four key respects. First, the semiotic instruments and the framework explicitly deal with interface sign design and evaluation. The results assist evaluators in analyzing each interface sign at five semiotic levels to investigate (a) the users' accuracy in interpreting the meaning of interface sign, and (b) the intuitiveness of interface signs for end users. Second, the results can support evaluators to find problematic interface signs, and describe the problems with interface signs. Third, the set of ontologies and the mapping features of ontologies assist evaluators in modelling the profiles of end users, and support the analysis of interface signs more precisely based on users' familiarity with ontologies. Fourth, the results support evaluators when recommending possible design solutions for problematic signs.

The SIDE framework is closely aligned with the W-SIDE (Web-Semiotic Interface Design Evaluation) framework developed by Speroni (2006). The results extend the W-SIDE framework at least in four key respects. First, a total of seven ontologies are conceptually proposed in W-SIDE, whereas the SIDE framework proposes a total of twelve ontologies based on empirical data. Moreover, the SIDE framework explores users' perceived difficulties in interpreting the meanings of interface signs that belong to a different kind of ontology. This finding will support practitioners in designing and evaluating the interface signs more precisely. Second, the W-SIDE framework is derived mainly for an information intensive web UI. A total of four empirical studies are

carried out on different kinds of websites and web applications to develop the SIDE framework. Thus, compared with the W-SIDE framework, the SIDE framework is more general for web UI design and evaluation. Third, although a few heuristics of the SIDE framework are similar to the heuristics of W-SIDE, most of the heuristics are new. Moreover, the heuristics in the SIDE framework are developed from empirical data and classified in five different semiotic levels. Fourth, the W-SIDE framework evaluates interface signs on two levels (syntactic and semantic), whereas the SIDE framework evaluates interface signs on five semiotic levels.

Comparing the results with other related work (e.g., Amare & Manning, 2006; Ferreira et al., 2005;2006; Liu et al., 1998), it can be claimed that the thesis is differentiated, aligned, or extended in the following respects. First, the results find a few heuristics for user interface design and evaluation that already exist in literature (e.g., present clearly the purpose of interactivity). The main reasons for this are: (a) the broader scope of the research questions and (b) the explorative nature of the studies carried out in the thesis. Second, the results are explicitly focused on interface signs, not on other dimensions of UI design. Third, the SIDE framework and semiotic instruments are developed grounded on empirical data. Fourth, the semiotic levels are different from other existing frameworks, and thus support the evaluation of interface signs in different semiotic levels. Fifth, the results provide empirical evidence for the heuristics that already exist in the literature. Sixth, the thesis provides a set of ontologies and a set of features related to these ontologies in order to support the design and evaluation of interface signs. Seventh, the thesis provides a set of procedural guidelines of how to use the proposed semiotic instruments and the SIDE framework. Eighth, the semiotic instruments and the SIDE framework are demonstrated and evaluated through empirical studies (i.e., the SIDE framework was tested with practitioners). Finally, the key focus of these results is (i) to provide support for the design of interface signs that are intuitive for end users, (ii) to evaluate the intuitiveness of interface signs, and (iii) to find the problems of interface signs in order to improve web usability.

Moreover, it is worth to discuss here how our results provide additional value to the existing non-semiotic works on interface design and evaluation. A few attributes and determinants of the SIDE framework are also addressed by other non-semiotic work on web design and evaluation. For example, attributes *language*, *cultural color* and *symbol* of determinant 'cultural marker' are stated by, for example, Cyr & Smith (2004), and Oh (2008); determinant 'color' is discussed by, for example, Marcus et al (1989); determinant 'position' is pointed by, for example, Blankenberger & Hahn (1991). Similarly, a few semiotic guidelines of the SIDE framework also exist in non-semiotic work on web design and evaluation. For example, a semiotic heuristic of the syntactic level 'follow a consistent interface sign design strategy' (see table 6) is related to, for

example, Nielsen & Mack's (1994) heuristic on 'consistency and standards', Shneiderman's (1987) guidelines 'strive for consistency', and to Norman's (1983) inference from research 'lack of consistency leads to errors'. The main reasons of founding a few determinants, attributes, and heuristics/guidelines that already exist in non-semiotic work on web design and evaluation were: (a) the interface sign is one of the major dimensions of web interface design, (b) the broader scope of our research questions, and (c) the explorative nature of the study methods used in our studies. However, our results are different from those found in existing non-semiotic studies in the following respect:

- First, the existing features (determinants and attributes) and heuristics were derived for whole web interface design and evaluation, not explicitly focused on interface sign design and evaluation.

- Second, our studies found that a number of features belonging to different semiotic levels of the SIDE framework are associated to the design and evaluation of interface signs. Thus, the existing features are not sufficient to assess the intuitiveness of an interface sign as well as to design user-intuitive interface sign. For example, in our studies, we found that interface sign *design uniformity* (i.e., 'consistency' in syntactic level) impacts on users' interpretation of the meaning of an interface sign, thus we could not exclude this from the proposed framework. *Design uniformity* is one of the attribute out of 66 attributes of the SIDE framework (e.g., if an interface sign is designed following only the features of 'consistency', then the sign may not be intuitive for end user; a number of other factors related to other semiotic levels may need to be considered to make this sign intuitive). Our studies derive all features and heuristics which are found relevant to design and evaluate web interface signs.

- Third, in a broader sense, a few semiotic guidelines of the SIDE framework might be treated as corresponding to some existing non-semiotic work on web design and evaluation. For example, a semiotic heuristic ('make effective use of ontological guidelines in interface sign design') of environment level (see table 6) corresponds to Nielsen & Mack's (1994) heuristic on 'match between system and the real world'. Nielsen (1995) describes this guideline as 'The system should speak the users' language, with words, phrases and concepts familiar to the user'. Our results will provide deeper knowledge to support UI practitioner in order to follow this guidelines more efficiently and effectively. For example, our studies derived what kind of presupposed knowledge (or ontologies) are used to interpret the meaning of web interface signs, how the ontologies conflict and multiple ontologies impact the understanding of the meaning of interface signs, what kind of ontological signs are difficult to interpret, how

practitioners can model users' profile based on their familiarity with different kind of ontologies, how practitioners can design and evaluate interface signs based on users' profile (i.e., users' familiarity with different kinds of ontology), etc. Thus, our results of environment level of the SIDE framework will provide a deeper understanding to apply this existing heuristic, and obviously only to the dimension of interface sign design of web design and evaluation.

- Fourth, many other existing non-semiotic guidelines do not directly correspond to our guidelines as the existing ones are derived for whole web interface design and evaluation; whereas our guidelines are derived explicitly for interface signs. For example, guidelines presented by Johnson (2007) ('don't complicate the users' task', and 'facilitate learning'), by Nielsen & Mack's (1994) ('error prevention'), by Shneiderman's (1987) ('prevent errors'), etc. focus on all dimension of web design such as navigational structure, content, information architecture, layout, interface signs. Interface sign is a very dominating element of every web UI, since interactions between users and web interfaces are mediated via interface signs. Some other studies (De Souza, 2005; Bolchini et al., 2009; Speroni, 2006) show that designing user-intuitive interface signs helps users to improve task completion performance, to reduce the rate of error while preforming a task, to improve their learning ability and allowing them to grasp the system's logic, and to ensure understanding and providing communication means. Our results provide fundamental insights to design and evaluate web interface signs to make them intuitive for end users. Our results thus can contribute as an additional toolkit to apply the existing non-semiotic guidelines for designing and evaluating web interfaces as a whole. For example, for users, a proper interpretation of interface sign (user-intuitive interface sign) is essential to understand the logic of the application, to learn how to use the system, to have a satisfactory use experience (Salgado et al, 2009; De Souza et al, 2006; De Souza & Cypher, 2008); thus to follow a non-semiotic guideline (i.e., 'facilitate learning' by Johnson(2007)) UI practitioners need to focus on designing user-intuitive interface signs; in such case our framework will support them to design user-intuitive interface signs in order to facilitate learning of the application.

- Fifth, to the best of our knowledge, no other non-semiotic work that has been carried out till date has specially focused on web interface signs as well as retrieved all features (determinants and attributes) related to interface sign design, evaluation, and users' interpretations. In our studies, we strived to find out all related features (16 determinants and 66 attributes) of users' interpretation of interface signs.

However, the final outcome of this research is an artefact (the SIDE framework), and this artefact, as a whole, is completely different from any other existing non-semiotic work on web design and evaluation. Our results will provide valuable insights to design and evaluate user-intuitive interface signs. Our results thus will act as an additional toolkit with the existing non-semiotic works to design and evaluate web interfaces. A more detailed discussion on how the SIDE framework can be used by UI practitioners is provided in the following subsection.

5.3 Implications for Practice

The results of this thesis have important practical implications as well. First, they will make practitioners aware of the importance of user-intuitive interface signs for successful web user interfaces. Second, the results will advance the practitioners' concepts for designing user-intuitive interface signs and for improving web usability. Third, they will support practitioners in understanding (or modeling) the users' profiles based on their level of familiarity with ontologies. This thesis does not provide any definitive procedures to apply to the results (semiotic framework and instruments) for UI design and evaluation; rather, it demonstrates a few example procedures in *Study II, VI, & VII* (Papers *II, V, & VII)*. However, for practitioners the results (semiotic framework and instruments) of the thesis may play a major role in UI design and evaluation in the following ways.

Raises awareness of semiotic concepts: The results may introduce a concept that practitioners have not encountered before. For example, practitioners may not be aware of the concepts of interface sign ontologies, paradigmatic relations among interface signs, and the like. In such cases, practitioners may gain these concepts from the thesis results, and can apply them effectively for designing and evaluating user interfaces.

Provides support for interface sign design. The results may support practitioners in maintaining a proper relation among an interface sign and (a) the meanings of this sign, (b) the ontology/ontologies referred to by the interface sign, and (c) the ontology/ontologies presupposed by the focused users in order to (re)design user-intuitive interface signs. Practitioners may follow the following steps to make interface signs intuitive for end users based on the results of the thesis: First, understand the studied application, and model the focused users' profiles based on their level of familiarity with ontologies. Second, understand the referential content or object that would be encoded as 'interface sign'. Third, (re)design an interface sign, or recommend possible design solutions for an interface sign.

Provides support for interface sign evaluation: The results may support practitioners in the evaluation of web interface signs either by an expert inspection or a user test. In case of expert inspection, practitioners may follow the procedure demonstrated in *Study VII* and discussed in section 4.2.6. In case of a user test, practitioners may follow the following steps: First, collect data on users' interpretations of interface signs and the difficulties they have in interpreting the meaning of the signs. In order to get this data, practitioners can conduct a sign test where practitioners will present the selected interface signs to the test participants; then ask them to interpret the meaning of the sign in the current context and also ask them to give a score on their perceived difficulties to get the meaning of an interface sign. Second, investigate and evaluate the problematic interface signs (e.g., signs that show very low intuitiveness scores, signs that are not interpreted accurately by the test-participants), and recommend possible design solutions.

Contributes to improve usability evaluation: The results primarily focus on web interface signs, which is one of the major dimensions of usability evaluation. Thus, these outcomes can also serve to improve usability evaluations of web applications by integrating the results with other usability evaluation methods (e.g., heuristic evaluation methods, laboratory based usability testing methods, user interviews, etc.). Integration could be carried out in several ways: (a) consider the results as a tool kit to plan and conduct the usability test, and also to analyze the test data; (b) use the proposed heuristics as a tool kit integrated with other heuristics (e.g., Nielsen's set of heuristics) to evaluate the user interfaces; or (c) conduct a sign test followed by a usability test, and analyze the data of the usability test with respect to the findings of the sign test.

Assists in interface sign design choice: In some difficult situations, practitioners may seek design assistance in order to make a sign more intuitive for end users. In such cases, the semiotic instruments (e.g., using effective amplification features, creating good relations with neighbor signs, etc.) may support practitioners to improve the intuitiveness of a sign.

The results give practitioners valuable and useful insights for the design and evaluation of user-intuitive interface signs. This will ultimately lead to improved web usability that is more attuned and adapted to the demands of practice.

5.4 Limitations

The thesis has several limitations that should be discussed. First, rather few participants were recruited for some studies, for example, a total of 4 participants were recruited in *Study III* and also in the first test of *Study VI*. In the research process we tried to alleviate this limitation by carrying out several

studies with a total of 74 participants to reach the results (semiotic instruments and framework) and to validate the results.

Second, the studies carried out use mainly university students as test-participants. It was important to recruit a heterogeneous sample of participants to find as many potential determinants and attributes as possible related to the users' interpretations of web interface signs. We, however, deviated from this design and recruited four hospital nurses as test participants in *Study III*; one researcher, and five company employees in *Study V*; and six usability experts in *Study VII*. Thus, we tried to overcome this limitation by recruiting a total of 74 participants with heterogeneous user profiles in terms of profession (i.e., students, nurses, company employers, research personnel, and usability experts), gender, age, country of origin, and familiarity with the studied applications, web domains, internet access, and the use of computers and mobile devices.

Third, *Study IV* was carried out through an expert inspection; thus the main limitation of this study is the possibility of inaccurate data extraction (e.g., extracting irrelevant data and failing to notice some relevant data). We tried to alleviate this limitation by carrying out the study meticulously based on the investigator's expertise followed by a focus group discussion. However, the semiotic instruments derived from this study are further validated by an extensive empirical user study (*Study V*), i.e., the semiotic instruments derived in the *Study IV* and also found in *Study V* are used for developing the SIDE framework (see the Table 5 in section 4.2.5).

Fourth, the SIDE framework is used only by the student participants in *Study VII* to evaluate the given sample of interface signs and the performance metrics are measured based on their evaluation. The expert participants did not use the framework to evaluate the given sample of interface signs; rather, they only gave their subjective feedback on the SIDE framework based on their expertise. However, although we remain confident that our results are effective, useful and reliable, it may prove worthwhile to validate the results by using the framework in real cases by experts/ practitioners.

Fifth, the data of most of the studies are analyzed mainly by a single researcher. An analysis of qualitative data (e.g., interview data) is generally subjective as it depends on people's opinions, knowledge, assumptions, and inferences. However, in the research process we tried to alleviate this limitation in the following ways: (i) several studies were carried out to create and validate the results of the thesis; (ii) in some cases, data analysis was carried out in collaboration with the thesis supervisors; (iii) systematic approaches were followed to analyze the study data.

Finally, critical features of semiotic and the nature of human interpretation is also a major limitation for this thesis. Semiotic deals with the sign and its referential object (i.e., the meaning of the sign). So, people need to interpret the sign to understand its meaning. It is nearly impossible to predict another person's interpretation based on a given 'object' (i.e., the meaning of the sign) and its 'representamen' (i.e., the sign) (Ferreira, 2004). Each individual makes his/her interpretation based on the context (e.g., background, culture, education, etc.) in which they find themselves at a specific point in time. In spite of having this critical feature, semiotic is widely used in HCI since the last few decades as discussed in chapter 2. Nadin (2001) stated to the HCI community that *"one cannot not interact; and because interaction is based on signs,…that is, one cannot avoid semiotic"*. Similarly De Souza (2005b) stated that *"Introducing design ideas to users through a careful engineering of efficient semiotic systems and interactive rhetoric (that does not need to be verbose at all) can help designers share responsibility for successful interpretive tasks with users"*. Again, the vastness and diversity of web users make it quite impossible to develop a user interface understandable and suitable for all users (Te'eni et al, 2007). Similarly, it is also impossible to design interface signs completely intuitive for all users. Therefore, designers have to make interface signs to be intuitive for the users in focus, and thus need to compromise with needs of other users. In spite of these constraints, we tried to produce the empirical evidence for designing and evaluating interface signs from a semiotic perspective, we tried to model the users in focus to make the sign intuitive to those users and also to improve the intuitiveness of interface signs for all users.

5.5 Suggestions for Future Research

The research question is very extensive and limited time frame, research scope and limitations made it impossible to provide final answers to the research question in one work. The studies were carried out to investigate five sub-questions that focused on web interface sign design and evaluation from a semiotic perspective; the choice of sub-questions focused on the state of the art of semiotic research in UI, understanding the importance of semiotic in UI design, semiotic instruments for user-intuitive interface signs, benefits of integrating semiotic in usability evaluation, and the applicability of semiotic instruments in UI design and evaluation. This subsection presents some suggestions for productive future research.

First, this study mainly considers the interface signs of web user interfaces and does not focus on interface signs for information systems in general (e.g., desktop-based applications, games, etc.). Moreover, the semiotic instruments are derived from the studies that are carried out in this thesis. Further research is needed to consider interface signs that are more general in information systems

applications (i.e., not only for web UI). Research in this direction will give more contributions (e.g., will provide more semiotic guidelines relevant to a particular determinant) and will generalize the outcome in order to move beyond the interface domain.

Second, this thesis does not consider user profiles for which the interaction paradigm and the interaction platform change radically (e.g. users with physical or cognitive disabilities). In such cases users' interpretations of interface signs may depend on different processes and elements. Focusing on these is an appealing area for improving the value and the applicability of the results found so far.

Third, the development of mobile applications has presented new challenges to (re)design user interfaces. It is difficult to design and evaluate a mobile UI with principles developed for desktop applications because of (Zhang and Adipat, 2005): (a) the mobile context, (b) connectivity, (c) the small screen size, (d) different display resolutions, (e) limited processing capability, (f) power and (g) data entry methods. The review study (see section 2.3 and 4.2.1, and *Paper I*) found that almost all semiotic research has been conducted for desktop based applications and only a few study focused on mobile interfaces. The outcomes of this thesis are mainly for desktop-based web user interfaces. Thus conducting the research on mobile user interfaces from a semiotic perspective will be at a starting point; it is still an open problem, and is a potential area for further research. Because, in order to design and evaluate mobile user interfaces it is not clear how much these outcomes may offer, what limitations may arise, and what specific semiotic instruments are needed.

Fourth, a promising future topic will be assessing the impact of the SIDE framework on the performance of usability evaluation. This could be done either (i) by carrying out two studies separately- one using the SIDE framework and another with any other usability evaluation method, and then compare the results, or (ii) by conducting two studies separately- one by integrating the SIDE framework with a usability evaluation method and another with only the usability evaluation method, and then compare the results. Further research in these directions will assess the value of the SIDE framework and may offer a more concrete procedure of using the SIDE framework for usability evaluation in order to improve the performance of usability evaluation.

Fifth, a number of studies found that culture plays a key role in user interface design (Hynes and Janson, 2007; Luna et al., 2002). Although the thesis finds a few attributes related to cultural issues (e.g., a few determinants and attributes on the social and environment level of SIDE framework), this does not mean that outcomes are applicable for designing and evaluating the culturally adapted user interfaces. One of the main reasons is that the studies do not explicitly focus on

cultural issues and culturally adapted UI. Therefore, further research should go beyond cultural issues to extend the proposed framework (e.g., derive more semiotic instruments related to cultural issues) for designing and evaluating the culturally adapted user interfaces.

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Part II:

Original Publications

Paper I

Islam, M. N. (2013). A Systematic Literature Review of Semiotics Perception in User Interfaces. *Journal of Systems and Information Technology*, Vol. 15 (1), pp.45-64.

Paper II

Islam, M.N., & Tétard, F. (2014). Exploring the Impact of Interface Signs' Interpretation Accuracy, Design, and Evaluation on Web Usability: A Semiotics Perspective. *Journal of Systems and Information Technology*, Vol. 16 (4).

Paper III

Islam, M. N. (2012). Semiotics Perception towards Designing Users' Intuitive Web User Interface: A Study on Web Sign Redesign. In H. Rahman, A. Mesquita, I. Ramos, and B. Pernici (Eds.), *Proceedings of the 7th Mediterranean Conference on Information Systems*, Lecture Notes in Business Information Processing , LNBIP Vol. 129, pp. 139-155, Springer-Verlag.

Paper IV

Islam, M. N. (2013). Towards Determinants of Designing User-Intuitive Web Interface Signs to Improve Web Usability. In M. Aaron (eds.), *Proceeding of the 15th International Conference on Human-Computer Interaction (HCI International 2013),* Lecture Notes in Computer Science, LNCS Vol. 8012, pp. 84-93, Springer-Verlag.

Paper V

Islam, M.N., & Tétard, F. (2013). Integrating Semiotics Perception in Usability Testing to Improve Usability Evaluation. In M. Garcia-Ruiz (Eds.), *Cases on Usability Engineering: Design and Development of Digital Products*, pp. 145-169, USA: IGI Global.

Paper VI

Islam, M.N. (2013). Towards User-Intuitive Web Interface Sign Design and Evaluation: A Semiotic Framework.

Submitted to: International Journal of Human-Computer Studies

Paper VII

Islam, M.N., & Bouwman, H. (2014). An Assessment of the Semiotics Interface sign Design and Evaluation (SIDE) Framework. In *Turku Centre for Computer Science (TUCS) Technical Report,* TR No - 1106, ISBN: 978-952-12-3048-6, April, 2014.

An Assessment of the Semiotics Interface sign Design and Evaluation (SIDE) Framework

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Abstract

A semiotic framework (Semiotic Interface sign Design and Evaluation - SIDE) was developed for user-intuitive interface sign design and evaluation. Examples of signs are small images, navigational links, buttons and thumbnails, with which users interact with web UIs. This paper presents an assessment of the SIDE framework. The focus is on (i) the quality of the SIDE framework for evaluation of interface signs, and (ii) the contributions of the SIDE framework from an evaluator perspective. Two empirical user studies were carried out, involving 23 participants. Data was collected via interviews, problem-solving assignments and feedback questionnaires, and analyzed using descriptive statistics and qualitative analyses. The study shows that the SIDE framework is applicable to designing and evaluating interface signs and helps improve the intuitiveness of interface signs.

Keywords: Human-computer interaction, user interface design, usability evaluation, ontology and semiotics.

TUCS Laboratory
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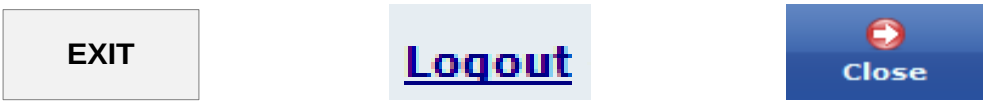
1. Introduction

The user interface (UI) is a key element of any web application. It encompasses a number of navigational links, small images, short texts, command buttons, thumbnails, images, symbols, icons, etc., which are defined in this paper as interface signs (see figure 1 and 2). End-users interact with user interfaces through interface signs. The content and functions of web applications are directed primarily through such interface signs, which make them crucial elements of web user interfaces. In this paper, the concept of *user-intuitive interface sign* is introduced, referring to an interface sign that makes it easy and intuitive for end-users to accurately understand its referential meaning. A user-intuitive interface sign needs to be transparent and reflect the actual content if it is to meet the needs of users, allowing them to go directly to the content that is essential to them. They do not need to click on an interface sign to see the referential content to understand the meaning of the sign in question. The example below shows three interface signs, retrieved from three different email applications. These signs were stand here for log out the user from the system. Since user interpret the interface signs to interact with web UI, we can assume that:



(a) (b) (c)

Figure 1. Example of three interface signs for log out the user from the web system

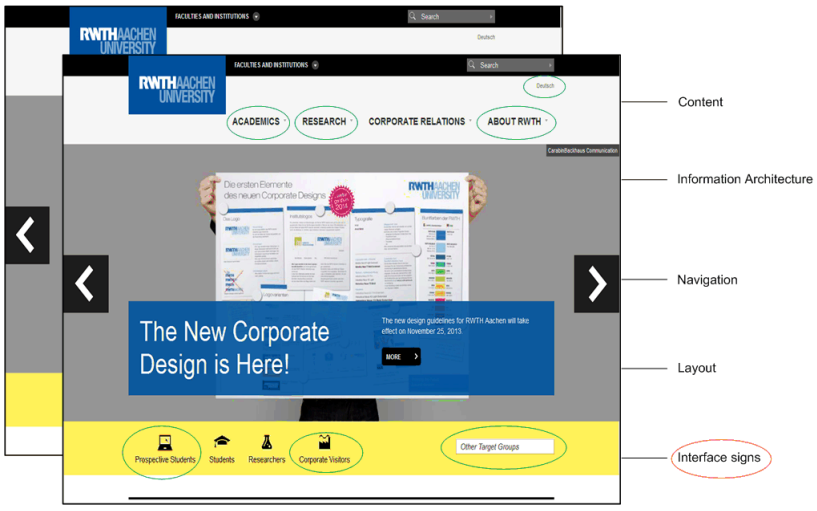


Figure 2. A snapshot of RWTH Aachen University shows (i) some interface signs marked by ovals, and (ii) user interface design and usability evaluation dimension (retrieved from www.rwth-aachen.de in April, 2014)

(i) Users may feel different level of difficulties or easiness to interpret the meaning of these signs; e.g., some users may interpret the meaning of sign (a) and (b) more easy than sign (c)

(ii) Users may not succeed to interpret the referential meaning of all these signs accurately; e.g., user may interpret the sign (c) as stands for closing an open window of an email-message.
(iii) Some users may be confused or unable to interpret the meaning of an interface sign. In order to understand the meaning of this sign properly, users may first need to click on that sign and explore its referential content/function.
(iv) Some users may interpret the meaning of a sign inaccurately and click on that sing to perform a task. In such a case, users will perform the task with worst performance (e.g., increase the task completion time, create the navigational error, fail to complete task properly, etc.). For example, a user may interpret the meaning of the sign (c) inaccurately as for closing an open window of an email-message. So, he/she may click on this sign in order to close the open window of an email-message. But, due to the inaccurate interpretation to understand the meaning of sign (c), he/she will log out from the system instead of closing the open window of an email-message.

This example shows that not all the interface signs are equally intuitive for all users to understand the referential meaning of the interface sign. Therefore, for a given user profile for a particular website; if users can interpret the meaning of an interfaces sign easily and accurately, then we can consider that sign as a user-intuitive interface sign. In HCI, such intuitiveness is an explicit goal in order to improve usability as well as to achieve better user experience, since interpretation is central to HCI and, at a low level, users interpret interface signs (e.g., icons, buttons, other controls) to understand the system's functionality and to interact with the system (Derboven et al., 2013).

Interaction between users and web interfaces is mediated via these interface signs. A study by Islam & Tétard (2014) shows that, if the interface signs are not intuitive, end-users spend a long time for finding the most suitable sign to obtain the information they are looking for; and increased interaction variation, which creates usability problems and reduces performance. The interaction variation is the difference between the number of interactions/clicks actually required to accomplish a task and the number of interactions/clicks performed by a user to perform the task in question (Islam & Tétard, 2014). Some other studies (e.g., De Souza, 2005; Bolchini et al., 2009; Speroni, 2006; Islam, 2011) show that using intuitive interface signs is essential in keeping users satisfied, improving their learning ability and allowing them to grasp the system's logic, improving the task completion performance, ensuring understanding and providing communication means.

The evaluation of web UI design and usability addresses a number of dimensions (Bolchini et al., 2009), including content, information architecture, navigation, layout and interface signs (see Figure 2). If two applications are identical with respect to content, information, navigation and layout, but different in terms of interface signs, applications with more user-intuitive interface signs offer better usability and end-user experience. This design principle focuses on sense production and interpretation, which refers to semiotics, the science of signs (Peirce, 1931:58).

The concept of sign is at the core of semiotics. Web user interfaces basically consist of a large number of interface signs. The key criteria to consider something a sign are (1) a sign should have some meaning, and (2) a sign should be interpreted. This means that it is the designer's task to make the interface signs of web UI meaningful, and to ensure that end-users can interpret the meaning of the interface sign correctly. In other words, the interface designer should encode the referential content or objects as an 'interface sign', so that end-users can correctly decode the sign and understand its referential meaning. Moreover, there is no one-to-one connection between the object and the sign; different users may interpret a given sign in a number of ways (see figure 3.a, the sign 'Member' is taken from a museum website) and various signs may have the same meaning (see figure 3.b). As a result, some signs may be very easy to interpret for some users, while others may not. Thus, end-users may perform a specific task appropriately when their interpretation matches the referential object (or meaning) of the interface signs, as assigned by designers. Therefore, it is important to understand why and how some signs are more intuitive than others. Semiotic Interface sign Design and Evaluation (SIDE) framework has been proposed for the design and evaluation of interface signs (Islam, 2014).

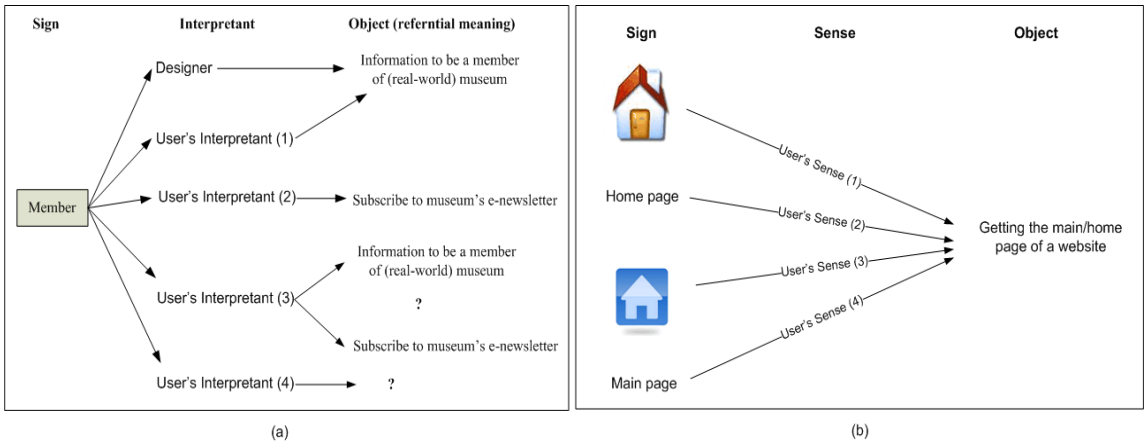


Figure 3. Possible interpretations of a web interface sign. Different interpreters (users) interpret (a) a sign referring to different object/meaning, and (b) different signs referring to the same object/meaning.

The objective of this study is to assess the SIDE framework in terms of thoroughness, validity, effectiveness, efficiency, reliability, accuracy, appropriateness and learnability, and to establish the characteristics that the evaluators consider to be important. The overall research question was formulated as: *How applicable is the SIDE framework to designing and evaluating the user-intuitive interface signs?* To provide an effective answer to this question, this paper is organized as follows. Related research, the introduction of the SIDE framework, and quality metrics for evaluating the SIDE framework are discussed in section 2. Next, we describe the research methodology; including the study procedures, participant profiles and data collection processes, in section 3. The results are presented in the section 4, and the results, implications for research and practice, and limitation are discussed in section 5.

2. Theoretical Background

2.1. Related Work

Over the last few decades, a number of studies have been conducted in the area of semiotics in HCI (Islam, 2013; O'Neill, 2005). De Souza (1993; 2005a) introduced the theory of semiotic engineering in HCI. According to semiotic engineering theory, a 'one-shot message' is sent from the *designer* to the *user* through the *system* to obtain specific outcomes or effects. An effective HCI includes a two-fold communication process: a) communication between designer and system, and b) interaction between system and user (De Souza, 2005a; 2005b; 2013; De Souza et al. 2001a; 2001b). The semiotic engineer analyzes the connection between system symbols (e.g., words, icons, graphical layout, buttons, links, etc.), semantics and functions, to understand the (designer-to-user) meta-communication. In De Souza's (2013) view, it is the ability to ensure that users receive the accurate messages sent by the designers that makes a design successful. Speroni (2006) developed a semiotic framework (Web-Semiotic Interface Design Evaluation) to evaluate information-intensive web user interfaces. The W-SIDE framework focuses mainly on interface signs. The semantics of interface signs and their understanding by end-users are analyzed. Speroni (2006) used the term 'ontology' to refer to a set of concepts or knowledge, presupposed on the part of users when they interpret the meaning of interface signs. For example, InterLocutor/Institution Ontology is related to the owner of the website concepts, Internet Ontology relate to concepts for Internet uses, and Website Ontology offers concepts related to a particular website. Andersen (1997) provided a methodological framework for analyzing HCI that is rooted in semiotics and shows how computer-based signs mediate people's interaction with computer systems. In Andersen's view, a user interface is *"a collection of computer bases signs, viz. all parts of system processes that are seen or heard, used, and interpreted by a community of users"* (Andersen, 1997, p. 143). User interface elements are also discussed by Nadin (1988). Nadin (2001) stresses the importance of including semiotics in HCI, arguing that that *"one cannot not interact; and because interaction is based on signs,…that is, one cannot avoid semiotics"* (Nadin, 2001, p.437).

In recent times, semiotics research in HCI has expanded in a number areas, such as (a) semiotic frameworks or models for UI; (b) semiotic approaches to analyzing the UI; (c) semiotics guidelines, principles or heuristics for UI and (d) semiotics concept in HCI designed to assess, integrate, evaluate, explore and demonstrate the semiotic theories, frameworks and design principles in HCI (see table 1)

Table 1. Examples articles of relevant semiotics work in HCI

Articles	Main outcomes	Descriptions
a) Semiotic framework for UI		
Barr et al., 2004	A semiotic model for user interface metaphor.	Application of Peirce's (1931-1958) triad (representamen, object, and interpretant) to metaphor of interface sign. This framework adopted the concept of Eco's (1976) unlimited semiosis.
O'Neill and Benyon, 2003a;2003b; O'Neill, 2005	A semiotic model of interaction	This model consists of four elements: sequential and concurrent syntax, the environment, the perception/action loop, and information artifacts.
French et al., 1999	A semiotic framework (shared meaning design framework -SMDF) to design and develop the e-commerce applications.	The framework provides support to improve the HCI performance (meaning, complexity and usability). The SMDF includes a total of six interrelated layers: HCI (objects, signs, semantic and surface level complexity), local contextual cues, organizational semiotics, cultural norms, and concepts of trust and security.
Speroni, 2006	A semiotic (W-SIDE) framework to design and analyze the information-intensive web UI.	The framework includes two levels: the syntactic level and the semantic level. The analysis of interface signs is also carried out according to these levels. The concept of 'ontology' is introduced to model the profiles of end-users.
b) Semiotic analysis method for the design and analysis of UI		
Bilotta and Pantano, 1995	A semiotic model to analyze icons.	This model analyzes and classifying the icons in graphical user interfaces. It includes three semiotic constructs: syntactic, semantic, and pragmatic.
De Souza et al., 2006	A semiotic inspection method (SIM) for evaluating the system communicability.	The SIM is developed based on the theory of semiotic engineering (De Souza, 2005). The core steps of SIM include the following: inspection of metalinguistic signs, then static signs after that dynamic signs; comparisons of the designers' meta-communication

		message generated in the previous steps; and evaluation of the quality of the entire meta-communication (i.e., communication between the designer-to-user via the system).
Roberto and Toppano, 2009	A semiotic framework to design and analysis the hypermedia	The model is proposed based on a narrative-structural framework that uses the following four levels of signification: semiotic square, semio-narrative, discoursive and textual.
Scolari, 2009	A methodology to analyze web interfaces.	This approach reflects the application of semiotics in HCI. It analyzes the interfaces on four levels: plastic, figurative, communicative, and meta-communication.
Triacca et al., 2005; Bolchini & Garzotto, 2007	A usability inspection method (Milano-Lugano Evaluation Method – MiLE+)	The MiLE+ was developed to evaluate web usability. It integrated the concept of semiotics to analyze the application-independent features of web interfaces.
Derboven et al, 2012	A semiotic analysis approach for multi-touch applications.	This approach uses the concept of semiotic engineering and provides support to obtain insight into the way users understand and use multi-touch interfaces.
c) Guidelines, principles or heuristics for UI		
Liu et al.,1998	Provide a set of general design guidelines for user interface design.	The guidelines are divided into the following categories, from a semiotics perspective: navigation, iconic representation, aesthetics and world of references.
d) Assess, integrate, evaluate, explore, and demonstrate semiotic theories		
Bento et al, 2009; Salgado et al, 2009	Demonstrate the applicability of the semiotic concept A semiotic model of interaction through interactive media.	They investigated and demonstrated the applicability of de Souza's et al (2006) semiotic inspection method (SIM) to a robot user interface to control a robot named e-Puck (Bento et al., 2009), and to analyze the ICDL (International Children's Digital Library) (Salgado et al., 2009).

Some studies have evaluated the quality and applicability of the proposed semiotic frameworks and analysis/evaluation methods: Reis & Prates (2013), for example, assess the characteristics of SIM, Speroni et al. (2006) shows the effectiveness of W-SIDE, and Bolchini & Garzotto (2007) measure the quality of MiLE+. These studies are discussed in greater detail in section 5, to compare them with our results.

To summarize, semiotics plays a significant role and adds value to HCI research, especially in the formulation of design principles of web user interfaces. The concept of semiotic is used in our framework (SIDE) with a focus on how to make web interface signs intuitive to end-users and improve web usability. Although the semiotic frameworks and models introduced here have their own merits, the proposed SIDE framework is different from the extant frameworks in the following respect (Islam, 2014): First, the SIDE framework is explicitly focused on interface signs, not on other design dimensions such as navigational structure, content, or information architecture. Second, the SIDE framework is developed and grounded on empirical data. Third, the semiotics layers (or constructs) of the SIDE framework are different from other existing frameworks. Fourth, SIDE framework is developed to analyze a sign in different semiotic layers. Fifth, The SIDE framework includes all features (16 determinants and 67 attributes) related to interface sign design, evaluation and users' interpretations. Finally, the ultimate objective of these outcomes is to support practitioners in the design of interface signs to make them intuitive for end user, as well as to evaluate the intuitiveness of interface signs to improve the overall usability and end user experience. In the next subsection, we briefly introduce the SIDE framework.

2.2. The SIDE Framework

The SIDE framework (see figure 4), which is proposed for the design and evaluation of user-intuitive interface signs, is based on empirical data collected over a period of three years (2011-2013). The framework includes (a) a set of determinants (themes) and attributes (sub-themes) of interface sign design and evaluation, and (b) a set of semiotic heuristics for interface sign design and evaluation. The SIDE framework includes the following five semiotic layers:

(i) Syntactic - This level comprises the features of interface sign presentation.

(ii) Pragmatic - The pragmatic level deals with the relation of interface signs to their interpretation or use.

(iii) Social - The social level deals with the meaning of the interface sign in terms of its social consequences.

(iv) Environment - The environment level deals with the environmental or surrounding factors that are collectively capable of affecting the users' behavior. The level builds on the users' *presupposed knowledge* or *ontology*. The environment level represents, (a) the users' knowledge and memory, and (b) an association of users' interpretations of interface signs with the referential meanings of the signs, because the users' memory and knowledge form the basis to understand the meaning of a sign.

(v) Semantic - The semantic level is the meaning of the sign and the relationships of (a) the interface sign, (b) the referential meaning of interface signs from a designer perspective, and (c) the referential meaning of interface signs from a user perspective.

Each layer subsequently defines determinants and determinants in turn have attributes. For example, 'clarity and readability' is a determinant of the syntactic level. This determinant does not directly impact the participants' interpretations of interface signs, but indirectly helps to interpret them appropriately. This determinant includes the following attributes: (i) *overlap (*the sign's texts that are merged by overlapping a few letters*)*; (ii) *likeness (*the signs' labels that are too similar to other signs*)*; (iii) *obscure (*signs that are unclear, hidden, and difficult to understand*)*; (iv) *distract (*signs that might be properly understandable by the end user, but are less important than what their appearance make out to be*)*; (v) *closeness (*signs that are placed too close to another sign*)*; (vi) *distance* (refers to the use of noticeable distance between related interface signs), and (vii) *conciseness (*the use of short and effective text as a sign label*)*. The framework proposes a set of semiotic guidelines for different layers of the framework. (Appendix I). The SIDE framework is discussed comprehensively in (Islam, 2014).

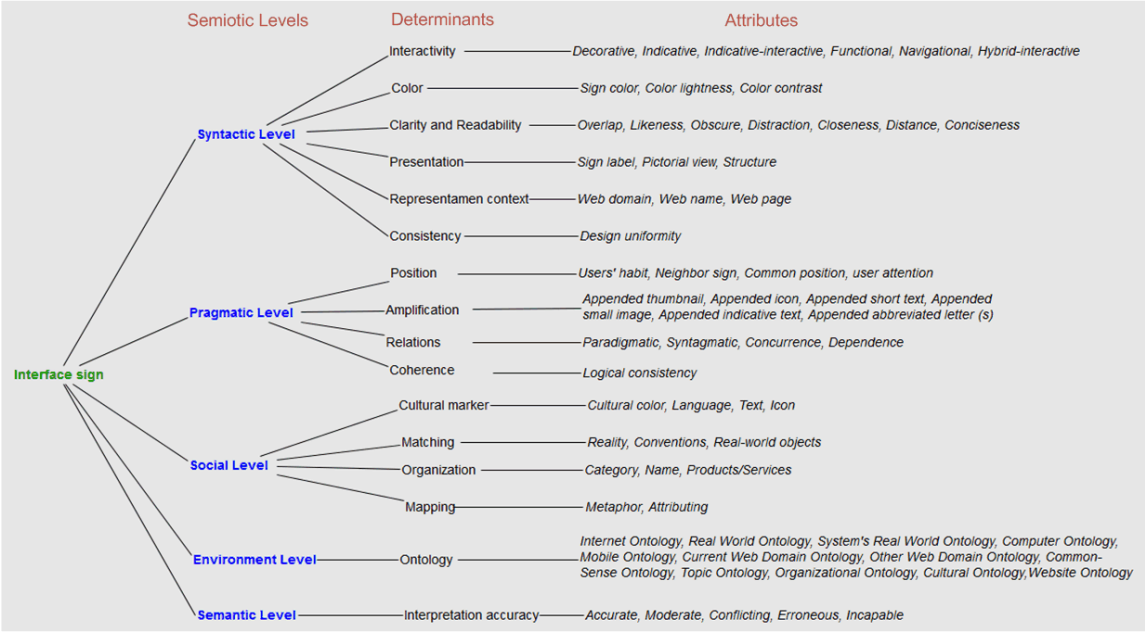


Figure 4. The SIDE framework: levels, determinants, and attributes

2.3. Quality Attributes

To assess the quality of the SIDE framework we conceptualized quality from a contingency perspective and defined it as a fit to certain requirements (Fenton, 1991). Quality needs to be decomposed into lower level criteria to be measurable (Bolchini and Garzotto, 2007). The criteria are defined in terms of performance-related measures, based on empirical usability data (i.e., identified usability problems, missing usability problems) as yielded by usability evaluation methods (Hartson et al., 2001). We operationalized these quality-related measures in terms of the following metrics:

Thoroughness measures the proportion of real problems (true positive) identified by an evaluation method to the real problems existing in the systems or interaction design under study (Hartson et al., 2001; Sears, 1997). Real problems are the problems approximated in our study to those found in a user test (see *Study I*, as discussed in section 3). Evaluation methods that have a low level of thoroughness are a waste of developers' or (re)designers' resources (time, effort), because they fail to identify a large number of relevant and important problems.

Validity measures the proportion of problems identified by an evaluation method that are real problems (true positive). In other words, validity measures show how well a method does what it is designed to do (Hartson et al., 2001; Sears, 1997). Evaluation methods with a low level of validity identify a large number of problems that are neither relevant nor real, which makes them a waste of resources.

Effectiveness measures the simultaneous effect of thoroughness and validity in a 'figure of merit' (Hartson et al., 2001). The value range for effectiveness will be the same as it is for thoroughness and validity (from 0 to 1) and will be low if either thoroughness or validity is low.

Reliability measures the consistency of evaluation results across different evaluators (Hartson et al., 2001), determining whether different evaluators, or groups of evaluators, tend to find a similar number of problems when applying a given technique. The value range for reliability is 0 to 1, where 0 indicates only chance agreement and 1 indicates perfect agreement, corrected for chance.

Efficiency measures how fast a method manages to identify a problem (Bolchini and Garzotto, 2007). It is measured as the rate of the number of different problems identified by an evaluator in relation to the time spent (De Angeli et al. 2003).

Learnability measures the ease of learning a method (Bolchini and Garzotto, 2007), based on the following factors: (a) the time needed by an evaluator to learn a method and be able to carry out an inspection with a reasonable level of performance; (b) participants' perceived difficulty in terms of learning or understanding the method and being able to carry out an evaluation, and (c) participants' perceived difficulty with regard to using the method in a real case.

Accuracy measures how well our framework helps identify the intuitiveness of interface signs. We measure accuracy with regard to identifying the level of intuitiveness (less, moderate and high) of interface signs as a proportion of the number of intuitive signs identified correctly by an evaluation method to the total number of evaluated signs.

Appropriateness measures the percentage of correctly applied heuristics (Bekker et al., 2008) and provides an indication of the evaluators' understanding of the method, since validity, thoroughness and effectiveness do not consider whether the problems were identified through the appropriate application of the evaluation method (Bekker et al. 2008).

The equations of measuring the performance metrics are presented in Appendix II. These performance metrics are used to evaluate the SIDE framework.

3. Study Method

The actual research includes two studies – referred to as *Study I* and *Study II*. An overview of the study method is presented in figure 5. A standard usability problem set is necessary to compute various performance metrics. Since determining the set of real problems is impossible, a user test was used to provide a standard problem set, as is done in comparing the performance of evaluation methods (Hartson et al., 2001; Bekker et al., 2008; Cockton et al., 2003). The usability problems determined by the user test (laboratory based test) are considered most often as a de-facto standard in studies of usability evaluation method performance (Landauer, 1995; Newman, 1998; Hartson et al., 2001). Therefore, a user test was carried out in *Study I* to test the intuitiveness of a set of interface signs and to identify the problems, i.e., a violation or lack of semiotic design guidelines/heuristics that reduced the intuitiveness of interface signs. The results of *Study I* are used as a standard against which to measure the performance metrics of the SIDE framework in *Study II*. Thus, *Study II* was conducted to collect data similar to *Study I*, through heuristic inspections (performed by evaluators/test-participants), and to obtain subjective feedback regarding the SIDE framework from the evaluator's perspective. Participants of *Study I* and *Study II* are referred as user and evaluators respectively, in order to avoid the confusion of referring to the participants to these studies.

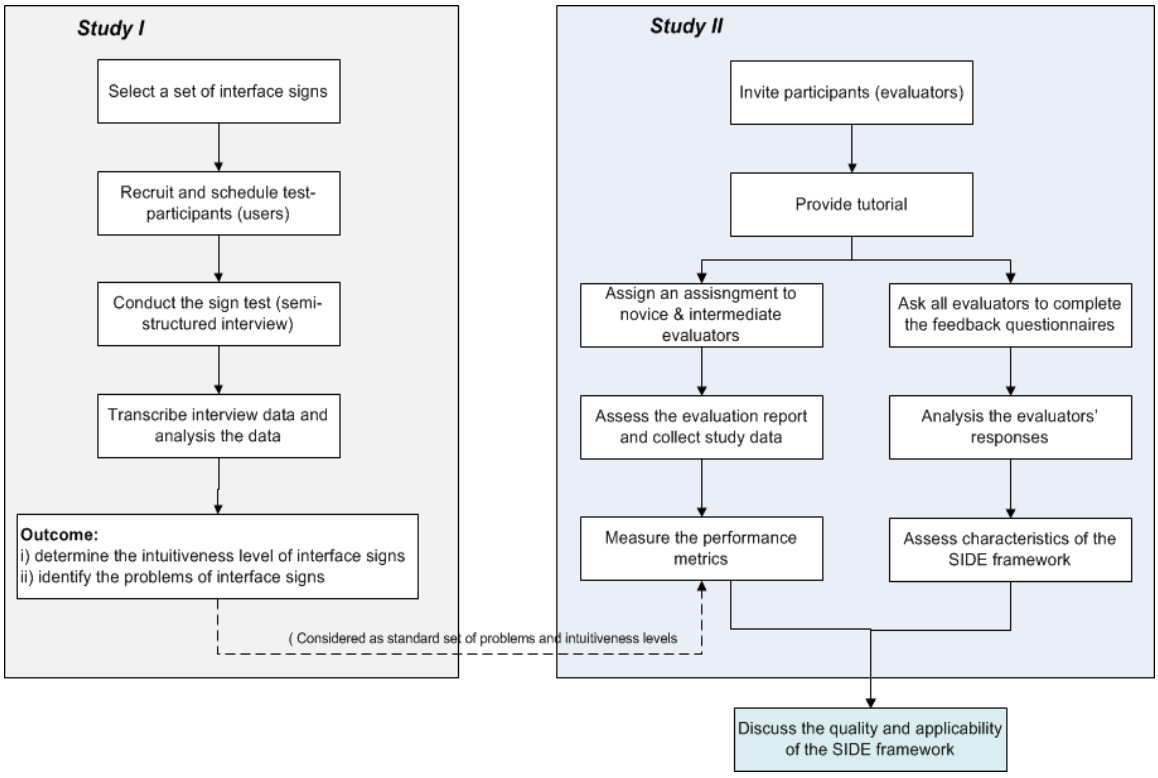


Figure 5. Overview of the study methodology

3.1. Overview of Study I

3.1.1. Participants

In all, six student participants (users) were recruited on a voluntary basis to conduct *Study I*. Five of them were under-graduate students and one was a graduate student. They were aged 21-30 (*m =25.33, SD = 2.62*). They all had extensive experience with Internet browsing via computer and mobile interfaces. None of them had experience with the websites from which the signs under study were retrieved. They had experience with accessing university websites and two of them had some experience with museum websites. None of them had experience with Dutch or German culture.

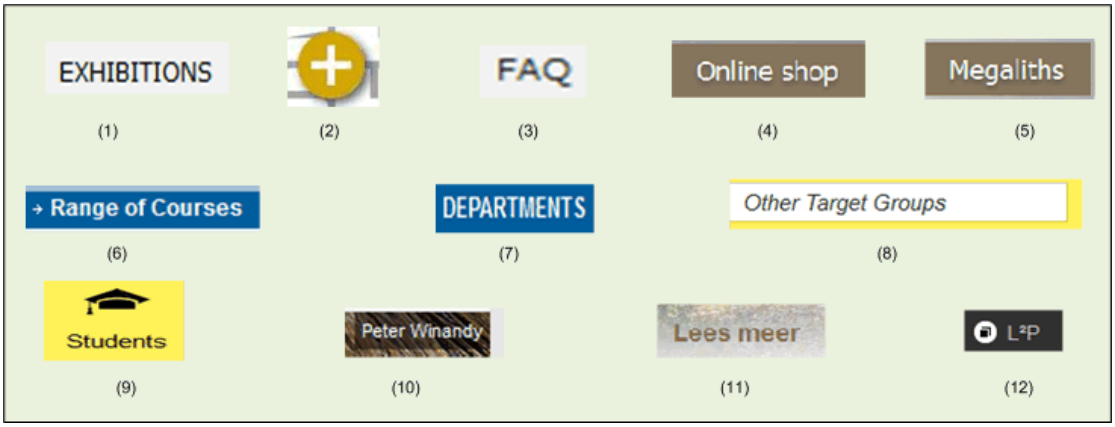


Figure 6. Set of interface signs

3.1.2. Procedure

The followings procedure was followed in *Study I* (see figure 5). First, 12 interface signs were selected from two university websites (Universität Trier and RWTH Aachen University) and two museum websites (Drents Museum and Hunebed Centrum Museum – Dolmen Central Museum). A few heuristics were employed to select the interface signs. These were: *(h1)* signs used to provide most common information or functionalities in a particular website; *(h2)* signs may have different level of intuitiveness; and *(h3)* some signs may have problems, and some other may not have any problems. Though during the test sessions interface signs were presented to the users with context, but due to the lack of space, here the signs are shown without context in figure 6. Second, students were recruited as test-participants. Third, the test was conducted for each user via semi-structured interviews at a usability testing lab. The following activities were followed in each test session with each user: (i) users signed the consent form and filled in pre-test questionnaires, (ii) a short introduction was given to inform the test subjects about the test in general: the test procedure, their role, etc., and (iii) they were asked to answer a set of questions for each interface sign (with context). They were not allowed to click on the signs, but only to respond to a number of questions, such as What could be the referential meaning of this sign? Why do you think this (user's response for the first question) is the meaning of this sign? When interpreting this sign how intuitive are they to you (less intuitive, average intuitive or highly intuitive; score: 1(not intuitive) – 9 (extremely intuitive))?

Do you have any suggestions for redesigning this sign that would make the sign more intuitive in terms of interpreting its meaning? Each session lasted about 25-35 minutes and was audio-video recorded. Fourth, the interview data was transcribed and then analyzed, using qualitative analysis and descriptive statistics.

3.2. Overview of Study II

3.2.1. Participants

Participants (evaluators) were invited by e-mail, university notice boards and personal contact. E-mail invitations were sent to Information Technology students at ÅAU and Information Systems Science students at UT, research and teaching personnel of both universities and some industry professionals. A total of 26 evaluators (19 students and 7 non-students) were attended in the tutorial sessions. A total of 17 evaluators (11 students and 6 non-students) successfully completed the given tasks. All students who have properly completed the tasks of *Study II* were received 1 (European Credit Transfer System – ECTS) credit point. Thus, *Study II* was carried out with a total of 17 participants (evaluators). They were divided into three sub-groups based on their UI design and evaluation experience – hereafter referred as *novice (n=7)*, *intermediate (n=4)*, and *expert (n=6)*. The *novice* evaluators had little experience with UI design and evaluation. Six evaluators had completed at least one academic course related to UI design and evaluation. Two evaluators had one month experience and contributed in a small projects related to UI design and evaluation. One evaluator had six months experience, but did not complete any related course or project. The *intermediate* evaluators had some experience with UI design and evaluation, i.e., they were intermediate beginners. They all had completed academic courses related to UI design and evaluation. They had 6-12 months of experience and contributed to about 5-7 projects related to UI design and evaluation. Both *novice* and *intermediate* evaluators were pursuing their MSc in computer science or information systems at Åbo Akademi University (ÅAU) or the University of Turku (UT) in Finland. The *expert* evaluators had experience with UI design and evaluation and were aged 27-61 (*m =37, SD = 11.42*). Three of them had experience both in an academic and industrial environment, two only in an industrial environment and one only in an academic environment. Five evaluators had completed academic courses related to UI design and evaluation. Evaluators had 2-20 years (i.e., 24 - 240 months) of experience and contributed to several projects *(m = 19.00)* related to UI design and evaluation. A summary of the evaluators' profiles is presented in Table 2.

3.2.2. Procedure

The following procedure was used in *Study II* (see figure 5). First, evaluators were invited and informed the possible dates and times of tutorial sessions. Second, a half day (3 hour) tutorial was provided. Tutorial was provided in three different dates, and participants were advised to attend in any one tutorial session. during each tutorial session we (i) introduced semiotics, interface signs and a few semiotics theories in HCI, (ii) briefly presented the SIDE framework and discussed 10-12 determinants and their attributes in detail, with examples, (iii) provided hands-on training to show how the SIDE framework can be used to evaluate interface signs, (iv) carried out a Q&A session; and (v), finally, briefly explained an assignment and supplied a set of feedback questionnaires on the SIDE framework. Only the novice and intermediate evaluators were asked to carry out the assignment, while all (novice, intermediate and expert) evaluators were asked to complete the feedback questionnaires. They were given two weeks to complete the assignment and respond to the feedback questionnaires. In the assignment, novice and intermediate evaluators were asked to evaluate a total of 12 interface signs (the same set of

signs that was tested in *Study I*) based on the SIDE framework. They were encouraged to follow a procedural guideline (see table 3) to evaluate the interface signs. A model of the users' profiles (deduced from the profiles of the participants in *Study I*) was provided to the novice and intermediate evaluators , because (a) the SIDE framework was developed for designing and evaluating the interface signs by considering the presupposed knowledge of focused end-users (i.e., the level of familiarity with the interface sign ontologies proposed in the SIDE framework); (b) the profiles of the users of *Study I* were seen as the targeted end-users for the applications under study; and (c) a single model of profiles of the end-users was considered by each evaluator. The novice and intermediate evaluators were also asked to keep track of their total learning time and evaluation time. Evaluators were all provided with the same learning material: (a) an article on the SIDE framework (Islam, 2014) that discussed the determinants and their attributes with at least one example, (b) a complete evaluation report of evaluating interface signs using the SIDE framework, following the procedural guideline presented in table 3, and (c) lecture slides. Finally, qualitative and quantitative data was collected from the novice and intermediate evaluators' reports and from the evaluator' (novice, intermediate and expert) responses to the feedback questions. The performance metrics, descriptive statistics and qualitative analysis were used to assess the quality and applicability of the SIDE framework.

Table 2. Profiles of *Study II's* participants (evaluators)

		Novice *(n=7)*	**Intermediate** *(n=4)*	**Expert** *(n=6)*
Gender	*Male / Female*	*6 / 1*	*2 / 2*	*5 / 1*
Age	*Mean (± SD)*	*26.43 (± 4.40)*	*25.25 (± 1.64)*	*39.17 (± 10.51)*
Education (latest degree)	*Bachelor/Masters /PhD*	*7 / 0 / 0*	*4 / 0 / 0*	*1 / 4 / 1*
Course completed related to UI design and evaluation	*Yes / No*	*6 / 1*	*4 / 0*	*5 / 1*
No. of contributed projects	*Mean (± SD)*	*0.43 (± 0.49)*	*6.25 (± 3.49)*	*19.00 (± 14.17)*
Years of experience	*Mean (± SD)*	*0.08 (± 0.17)*	*0.75 (± 0.25)*	*8.00 (± 6.08)*
Familiarity with the concepts of semiotics in UI/HCI	*Yes / No*	*0 / 7*	*0 / 4*	*0 / 6*
Other ways of familiarity with UI design and evaluation	*Yes / No*	*0 / 7*	*1 (MSc thesis) / 3*	*3 (teaching, consultancy , research) / 3*

Table 3. Procedural guidelines to evaluate interface signs

1. Understand the application and model the profiles of end-users
   - Understand the application: the domain, name, purpose and functionality of the application (i.e., what do they want to communicate or provide?).
   - Model the profiles of the focused end-users based on their familiarity with ontologies.
2. Evaluate or investigate the selected interface sign

   Step 2.1: Understand the referential meaning of the selected interface sign.

   Step 2.2: Analyze or evaluate the selected interface sign. (What properties of the signs are used? What properties are missing?)

   Step 2.3: Give the intuitiveness score (1-9; 1: less intuitive, 9: highly intuitive), How accurately can the user interpret the sign? How complicated or difficult is it for the users to interpret this sign? How certain or confident are the users in their interpretation? How transparent is the sign in terms of its actual content/meaning?

   Step 2.4: Recommend possible design solutions, where necessary, to improve the intuitiveness of the sign. (How can the sign be made more intuitive to end-user? What properties of the signs can be used to improve the intuitiveness of the sign?)

Task 1 needs to be carried out once for each application, while task 2 needs to be carried out repeatedly for each sign selected for evaluation.

4. Study Results

We discuss the results from the two studies at the same time by first looking into the results, based on the performance metrics, before we present the results with regard to the SIDE framework.

4.1. Measuring the Performance Metrics

Study I provides two results. Firstly, it showed that (see figure 6) highly intuitive signs (*mean value m=7 to m≤ 9*) are 'EXHIBITION', 'FAQ', 'Online shop', 'DEPARTMENTS', and 'Students' (i.e., sign1, sign3, sign4, sign7 and sign9 in figure 6); moderately intuitive signs (*mean value: m>3 to m< 7*) are 'Range of Courses', 'Other Target Groups', and 'Peter Winandy' (i.e., sign6, sign8, and sign10 in figure 6)*;* and less intuitive interface signs (*mean value: m=1 to m≤ 3*) are 'plus sign', 'Megaliths', 'Lees meer', and 'L^{2}P' (sign2, sign5, sign11, and sign12 in figure 6). Secondly, the study identified a total of 32 problems with regard to the interface signs. These results are presented in Appendix III.

Figure 7. Screenshot (part of) of RWTH Aachen University's homepage

The evaluator reports were examined and analyzed in detail, with the following results (see table 4): (A) the number of signs identified correctly with regard to their accurate level of intuitiveness (i.e., high, mid, or less), (B) the number of problems identified by evaluators, (C) the number of problems identified correctly (Hit) by the evaluators, (D) the number of problems identified inaccurately as problems (false positive), (E) the total number of heuristics/guidelines applied to identify the problems and intuitiveness of interface signs, (F) the number of hours spent learning to use the framework (learning time), and (G) the number of hours needed to apply the SIDE framework to evaluate the assigned interface signs (evaluation time); evaluation time did not include the time needed to write the evaluation report.

Table 4. Summary of the evaluation of interface signs in *Study II*

Evaluators	(A)	Real problems (B)	Hit (C)	False positive (D)	Heuristics applied (E)	Learning time (F)	Evaluation time (G)
N1	9	35	23	12	39	7.92	3.22
N2	8	41	27	14	44	4.17	4.67
N3	11	23	23	0	29	4.50	4.00
N4	8	21	10	11	36	5.00	3.17
N5	8	31	15	16	48	6.00	7.17
N6	9	29	15	14	41	4.50	5.00
N7	8	20	18	2	34	5.50	2.00
I1	10	26	25	1	32	3.92	3.25
I2	12	24	22	2	27	4.17	3.17
I3	10	47	30	17	49	3.63	2.53
I4	10	34	23	13	38	5.50	1.50
N: novice evaluator; I: intermediate evaluator A: No. of sign's intuitiveness level identified correctly							

An example of a Hit is the following: the 'Students' sign (see figure 7 and sign 9 in figure 6) actually stands for providing content and information for the current student. Three users found it difficult to interpret the meaning of this sign (in *Study I*). They thought that it was either (i) for alumni students, because of the appended graduate hat icon, or (ii) for current students, because of the sign 'Prospective Students', which is placed to the left of this sign. One user responded "*…This sign may be for alumni or those who will graduate…Oh! It may be for local students, as the neighboring sign is for prospective students….I don't know! It may be for alumni due to the graduation hat sign…."* This problem was predicted by two evaluators (in *Study II*). One evaluator recommended changing the icon ("*…the icon could be changed to another icon that better resembles current student…"*), and another evaluator recommend changing the sign label to adhere the design consistency with the neighboring sign ("*….change the sign's labels to 'Current Students' or 'Enrolled Students' – because there is another sign that says 'Prospective Students'…. "*). An example of a 'false positive' is the following: none of the users in *Study I* voiced any objection regarding the interactivity of the 'Students' sign. One

evaluator in *Study II* indicated that 'the interactivity purpose (e.g., decorative, interactive, or indicative) of this sign is not clearly present'. That makes this problem a 'false positive'.

Table 5. Summary results of quality metrics

		Novice *(n=7)*	Intermediate *(n=4)*	All Evaluators *(n=11)*
Thoroughness	*Mean (± SD)*	*0.58 (± 0.17)*	*0.78 (± 0.10)*	*0.66 (± 0.18)*
Validity	*Mean (± SD)*	*0.67 (± 0.19)*	*0.80 (± 0.14)*	*0.72 (± 0.19)*
Effectiveness	*Mean (± SD)*	*0.41 (± 0.19)*	*0.62 (± 0.09)*	*0.49 (± 0.19)*
Reliability		*0.71*	*0.88*	*0.73*
Efficiency	*Mean (± SD)*	*5.13 (± 2.32)*	*10.45 (± 3.38)*	*7.07 (± 3.76)*
Learning ability	*Mean (± SD)*	*5.37 (± 1.20)*	*4.30 (± 0.72)*	*4.98 (± 1.17)*
Accuracy	*Mean (± SD)*	*8.71 (± 1.03)*	*10.50 (± 0.87)*	*9.36 (± 1.30)*
Appropriateness	*Mean (± SD)*	*0.51 (± 0.16)*	*0.70 (± 0.10)*	*0.58 (± 0.17)*

Table 5 shows the results of quality metrics. The results show the mean and standard value considering the group size of one evaluator. We summarized the results of quality metrics as follows:

- *Thoroughness* indicates that more than half and more than three-fourths of all real problems are identified correctly by the novice and intermediate evaluators, respectively.
- *Validity* shows that novice evaluators correctly identified about two real problems out of every three identified problems (i.e., average validity is 0.67), while intermediate evaluators identified about four real problems out of every five identified problems (i.e., average validity is 0.80). The result indicate that novice and intermediate evaluators spent about 33% and 20% more effort, respectively, on identifying problems that are not real problems.
- *Effectiveness* indicates the simultaneous effect of *thoroughness* and *validity*. The results indicate a low level of effectiveness when either thoroughness or validity is low. The mean values for effectiveness were 0.41 and 0.62 for novice and intermediate evaluators, respectively.
- *Reliability* measures the consistency in identifying real problems among different evaluators. The results showed less than one-third of chance agreement (i.e., reliability is 0.71) among novice evaluators, and a relatively low change agreement (i.e., high reliability) among intermediate evaluators in terms of identifying real problems.
- *Efficiency* shows that novice and intermediate evaluators can identify about 5 and 10 real problems, respectively, in one hour.
- *Learnability* shows that novice and intermediate evaluators spent more than five and four hours, respectively, on understanding the SIDE framework.
- *Accuracy* shows that more than 66% and 80% of the total interface signs' levels of intuitiveness were accurately identified by novice and intermediate evaluators, respectively.

- *Appropriateness* showed that, on average, novice and intermediate evaluators correctly applied more than 50% and 70% of the heuristics, respectively, to evaluate the interface signs.

As expected, a few interesting aspects emerged from the results regarding the quality metrics (see the Table 5 and figure 8):

a) The intermediate evaluators showed a better performance than the novice evaluators. Considering the values of performance metrics for all evaluators, the results showed that the evaluators showed a higher performance than the novices, but a lower performance than the intermediates. In this study, the evaluators carried out an evaluation based on the heuristics of the SIDE framework, and the results indicate that evaluators who have experience with UI design and evaluation understand the heuristics of the SIDE framework with less effort (e.g., *learnability* is 4.30 and 5.37 for intermediates and novices, respectively) and are able to apply the framework in real cases more accurately (e.g., the value of *appropriateness* is 70.34 and 50.92 for intermediates and novices, respectively). The result are as expected, as the evaluation was carried out based on the heuristics proposed in the SIDE framework, and expert evaluators have the knowledge needed of understand the heuristics more quickly (e.g., *learnability* is 4.30 and 5.37 for intermediates and novices, respectively), and are better able to apply the heuristics to practical cases (e.g., *appropriateness* is 0.70 and 0.51 for intermediates and novices, respectively).

b) *Appropriateness* indicates that evaluators did not understand or apply the framework accurately. The results also indicate that understanding the framework better will take more time than the value measured for *learnability*. However, the learnability results indicate, as mentioned before, the approximate time needed by an evaluator to learn a method and be able to carry out an inspection activity with a reasonable level of performance.

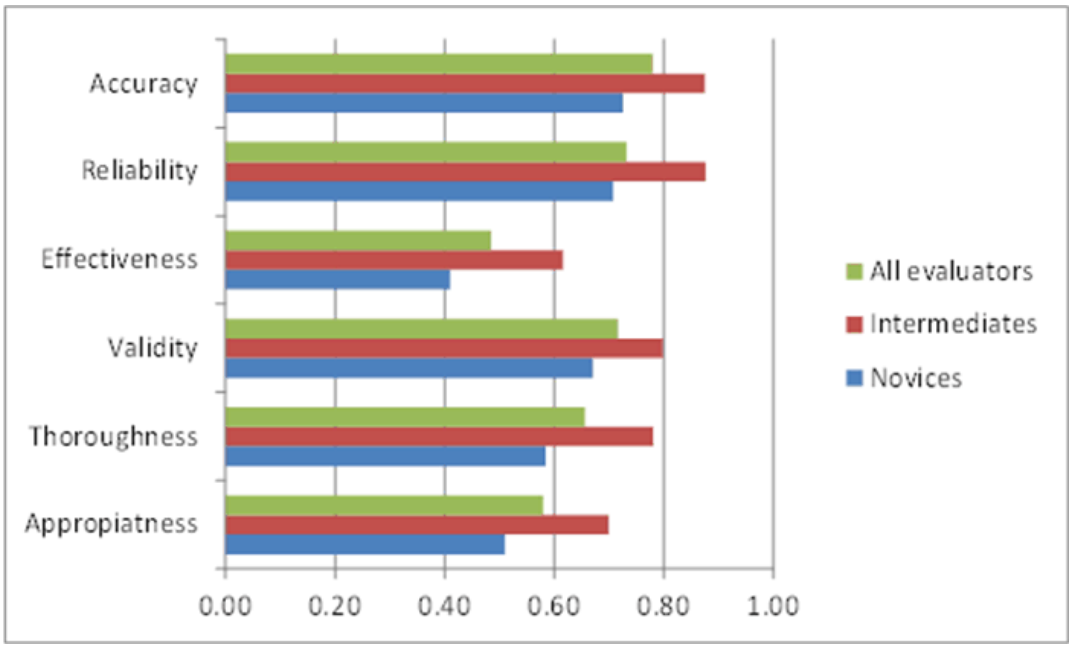


Figure 8. The results of quality metrics for novices, intermediates, and all evaluators

c) The results of efficiency show that the evaluation of a total of 12 interface signs took a long time. However, seeing the results regarding *appropriateness* and *validity*, we can assume that, if the evaluators learn and apply the framework more accurately, the *efficiency* results may be better; because they will spend less time identifying false positive problems.
d) Seeing the overall results in Table 5, we can assume that the value of *thoroughness*, *validity*, *effectiveness*, *reliability* and *efficiency* will be better if the evaluators apply the heuristics of the SIDE framework more accurately (i.e., if the *appropriateness* is improved). Although in such case, evaluators will spend more time learning to use the framework precisely (i.e., *learnability* will be low), but this will ultimately improve the evaluation performance with regard to other metrics.
e) The *accuracy* of identifying the level of intuitiveness of interface signs is better when the *appropriateness* and other evaluation performance metrics show better results.

4.2. Assessing Characteristics of the SIDE Framework

4.2.1. Subjective assessment of close-ended questions

In this section, we discuss the results of analyzing the data for the assessment of the SIDE framework. The mandatory close-ended statements were related to the following four themes: (i) the ease-of-use of the framework, (ii) the contribution of the framework, (iii) how the framework may be used and (iv) future use of the framework. A summary of the result is presented in Table 6.

- Looking at the scores for each group, which are presented in greater detail in table 6, the variation in scores is limited, but still interesting. The detailed results (i.e., mean values) show that both (a) experts (who do not use the framework) and (b) novice and intermediate evaluators (who have used the framework) did not disagree with statements related to any themes (i.e., mean values ≤ 3); intermediate evaluators were neutral ($m = 3$) with regard to (a) the framework is easy to apply in real cases (statement 1.3 in table 6), and (b) the use of framework in future (statement 4.1 and 4.2 in table 6). However, looking at the overall scores related to all main themes (see figure 9 and the bold font rows in table 6), the results show that each group of participants is in agreement with all the statements.
- Although the evaluators agreed with the statements related to the ease-of-use of the framework, the overall score for this theme was 3.5 and 3.67 for the intermediate and novice evaluators, respectively (see figure 9). This indicates that the evaluators have some difficulty in understanding and using the framework (e.g., intermediates mean score with the statement 1.3 was 3.00). However, the experts indicated that the framework is not difficult to understand and use in real cases ($m = 3.94$).
- With regard to future use, intermediates are almost at a neutral position ($m=3.17$), while the experts and novices to a large extent agree with the statements related to this theme. The intermediate evaluators to a large extent agree with the framework's contributions ($m = 3.81$) and with how the framework may be used ($m = 3.75$). We can assume that (a) they are not willing to use the framework in the future because of the time and effort needed to learn to apply the framework to real cases (e.g., their mean score for the statement 1.2 and

1.3 was 3.5 and 3.00, respectively), or (b) they may not envisage a career as designers or evaluators, as suggested when one intermediate evaluator disagreed with statements regarding future use by himself (i.e., gave a score of 2 to statements 4.1 and 4.2), but indicated he would recommend the framework to his colleagues and friends (i.e., gave a score of 4 to statement 4.3).

Table 6. Summary results of participant feedback (Score: 1-5; 1: Strongly disagree, and 5: Strongly agree)

	Novice *Mean (± SD) N=7*	**Intermediate** *Mean (± SD) N=4*	**Professionals** *Mean (± SD) N=6*
1. Ease of use of the framework	***3.67 (± 0.64)***	***3.50 (± 0.96)***	***3.94 (± 0.85)***
1.1 The framework is easy to understand	*3.89 (± 0.64)*	*4.00 (± 0.71)*	*3.67 (± 0.94)*
1.2 The heuristics are easy to understand	*3.57 (± 0.49)*	*3.50 (± 1.12)*	*4.33 (± 0.47)*
1.3 The heuristics are easy to use in designing and evaluating the interface signs	*3.57 (± 0.73)*	*3.00 (± 0.71)*	*3.83 (± 0.90)*
2. Contribution of the framework	***4.29 (± 0.75)***	***3.81 (± 0.73)***	***4.25 (± 0.52)***
2.1 The framework will help design user-intuitive interface sign.	*4.43 (± 1.05)*	*3.50 (± 1.12)*	*4.00 (± 0.58)*
2.2 The framework will help evaluate or analyze the interface sign.	*4.14 (± 0.64)*	*4.00 (± 0.00)*	*4.33 (± 0.47)*
2.3 The framework will help the usability evaluation process	*4.29 (± 0.45)*	*3.75 (± 0.43)*	*4.17 (± 0.37)*
2.4 The framework may introduce new concepts for designing and evaluating the interface signs that the practitioners may not encounter before (e.g., concept of ontology, pragmatic relationships, etc.)	*4.29 (± 0.70)*	*4.00 (± 0.71)*	*4.50 (± 0.50)*
3. How the framework may be used	***3.86 (± 0.79)***	***3.75 (± 0.66)***	***4.21 (± 0.82)***
3.1 As a tool integrated with other usability evaluations approaches.	*4.29 (± 0.45)*	*3.75 (± 0.43)*	*4.33 (± 0.75)*
3.2 As a tool to recommend possible design solution or guidelines.	*4.00 (± 0.76)*	*3.75 (± 0.43)*	*4.33 (± 0.75)*
3.3 As a tool integrated with heuristics that are developed (e.g., Nielsen's set of heuristics) to design and evaluate UIs.	*3.57 (± 0.49)*	*4.00 (± 0.71)*	*4.33 (± 0.75)*
3.4 As a stand-alone tool to design	*3.57 (± 1.05)*	*3.50 (± 0.87)*	*3.83 (± 0.90)*

and evaluate the UI.

4. Future use	***4.10 (± 0.61)***	***3.17 (± 1.07)***	***4.17 (± 0.60)***
4.1 Interested in using the framework in the future to design and evaluating the interface signs	*4.14 (± 0.64)*	*3.00 (± 1.00)*	*4.00 (± 0.58)*
4.2 Will use the framework in the future, especially for designing and evaluating the interface signs	*4.00 (± 0.76)*	*3.00 (± 1.22)*	*4.33 (± 0.47)*
4.3 Would recommend these outcomes to others (my colleagues)	*4.14 (± 0.35)*	*3.50 (± 0.87)*	*4.17 (± 0.69)*

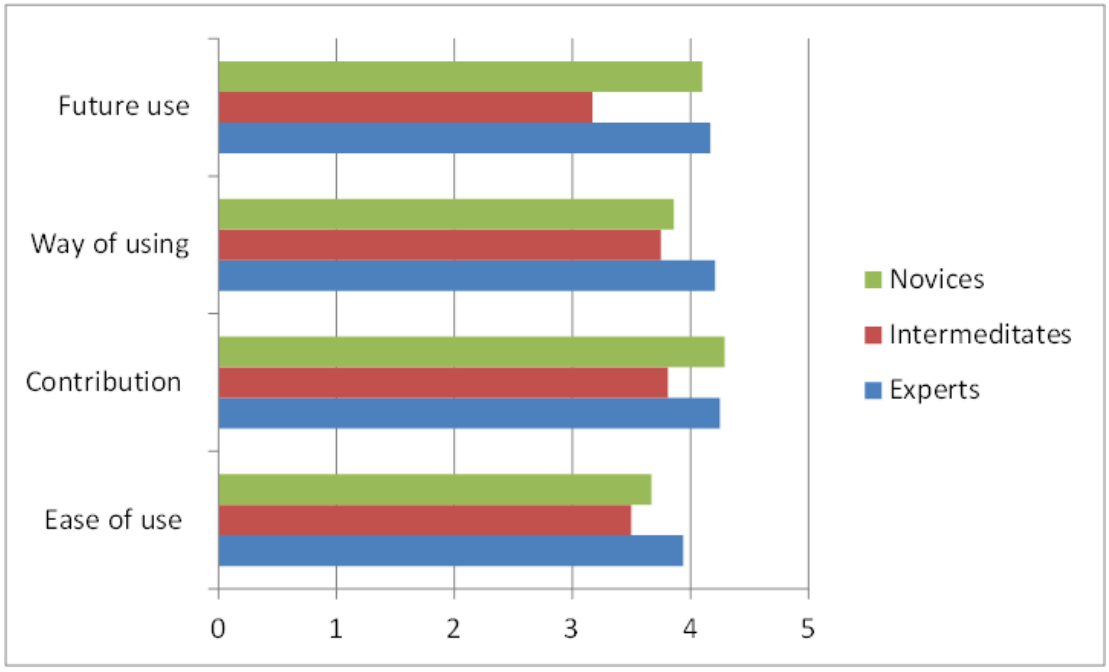


Figure 9. Mean values of close-ended questions

- A comparatively higher score was given by the participants in terms of the contribution of the framework and how the framework may be used, which means that the SIDE framework helps design and evaluate user interfaces, and practitioners can use the framework in a number of ways (e.g., as a stand-alone tool or integrated with other approaches).
- The results also showed that experts to a large extent agree with all the statements. Their intention regarding the future use of the framework sheds a positive light on the value of the SIDE framework. Experts to a large extent agreed that it is not hard to learn to apply the framework (with a score of 3.94). This result is also interesting, because it indicates that less experienced people may experience some difficulty in understanding and applying the framework. However, the reasons for giving low scores to the themes related to ease-of-use

and future use are discussed in greater detail based on the responses to the open-ended questions, in the following sub-sections.

4.2.2. Subjective Assessment of open-ended questions

In this section, we discuss the drawbacks and limitations of the SIDE framework based on open questions (See Appendix IV and table 7 for results). The discussions also include notations about changes made to the framework in response to the feedback.

Table 7. Benefits and drawbacks of the SIDE framework and the number of participants that mentioned them

		Novice	Intermediate	Expert	Total
Benefits	*Broadness of the framework*	4	3	2	9
	Useful tool	3	5	5	13
	Structured, documented and thorough	3	3	3	9
	Easy to understand	1	1	1	3
	Semiotic strength in HCI	0	0	1	1
	Valuable and recommended	0	1	3	4
Drawbacks	*Unfamiliar terminologies*	0	1	4	5
	Insufficient learning resources	1	1	4	6
	Complex hierarchical depth	1	1	1	3
	Excessive features	1	0	1	2
	Too structured	0	1	2	3
	Costs time and effort	1	3	1	5

We found the following benefits by analyzing the participants' responses to the open-ended questions:

B1. Broadness of the framework - A total of four novices, three intermediates and two experts mentioned that the framework is detailed and covers every aspect of interface sign design and evaluation, as indicated in the following examples: *"…It tackles different angles from different directions for interface signs…", "…I like the versatility of the semiotic heuristics. It covers pretty much every aspect of analyzing an interface sign…. ", "…The heuristics are detailed and covered almost every possible evaluation of a sign…"* and *"…I like the level of detail in which the framework has been sketched to include all aspects of the interface signs…"*

B2. Useful tool – The responses showed that they consider SIDE to be a useful tool that supports the effective design and evaluation of interface signs, which is exactly what it was designed to do. This result matches the responses to the close-ended questions about

'contribution of the framework'. The results obtained from the two questionnaires indicate that participants were more in agreement on this issue – the usefulness of the SIDE framework for interface design and evaluation, as indicated by following few examples: *"…I find that this framework is very useful. It was helping me a lot when evaluating those signs. It summarizes all …."*, *"…I find the framework to be very interesting and useful…"* and *"….I think the proposed framework is standard and useful for designing user interfaces with better user experiences…"*

B3. Structured, documented and thorough – A total of nine participants indicated they considered the framework to be structured, properly documented and thorough: *"…It is systematic and thorough…", "…The heuristics are presented with clear and concrete actions/indications…", "….the categories are good and clear…."* and *"….the heuristics are present very concisely and with the heuristic table it will be very easy to evaluate all the signs in less time…"*

B4. Easy to understand – two evaluators and one expert mentioned that the framework is easy to understand. Since only a few participants mentioned this issue in response to the open-ended questions, this result indicates that our findings from the close-ended questions are still viable, i.e., the framework is not all that easy to understand and apply for most participants: *"…Everything organized and documented in a way to easily understand and apply when designing the UI…", "…The method is easy to understand, detailed, and still easy to remember…"* and *"….Overall good and easy to understand and use…."*

B5. Semiotic strength in HCI - one expert mentioned that the use of semiotics adds values to the SIDE framework. Although he was not familiar with semiotic theories for HCI, he realizes the strength of semiotics in HCI through the SIDE framework. The participant's view strengthens the authors' claim that semiotic aspects are important to UI design and evaluation. This response also indicates the value of SIDE framework, since the framework is grounded in the theory of semiotics: *"… this framework greatly helps to map and explain the scope of the semiotic research field…"*

B6. Valuable and recommended - Three experts and one evaluator mentioned that the framework is valuable and that they would recommend it. This is very much related to benefits *B1* and *B2*, because the participants may experience this benefit due to the broadness and usefulness of the SIDE framework. The results highlighted the value of SIDE framework, because 50% of all the experts again highlighted this benefit in their answers to the open-ended questions, although the mean score related to the theme of future use was 4.17 (see table 6). Again, although the mean score for future use by intermediate evaluators (in close-ended questions) was not high enough, one out of four evaluators mentioned the framework as being valuable and to be recommended: *"….Well, it is the best heuristics for evaluating interface signs that I have seen…It is actually also the only one that I have seen. The points seem relevant to me, but I have not tried to apply them yet…."*, *"…I think the framework is valuable and recommended…", and "…I think the framework provides a quite good set of things to keep in mind when designing or evaluating an interface, and I would recommend it to people who are unfamiliar with the subject…"*

The analysis of the participants' responses to the open-ended questions reveals the followings drawbacks of the SIDE framework:

D1. Unfamiliar terminologies - Four experts and one intermediate evaluator mentioned that the framework includes some unfamiliar terminologies. For example, one expert responded: *"…. Some difficult terms like syntagmatic, which is not in my vocabulary, may also cause difficulties for UI practitioners…."* Participants mentioned the following terms as being unfamiliar: semantic, pragmatic, syntagmatic, umwelt, paradigmatic, de-notational, ontology, representamen and coherence. This result showed that participants are unfamiliar with the terminology derived from the theory of semiotics. The term 'ontology' was borrowed from other related works. Moreover, the profiles of our participants showed that they were not familiar with semiotics theories and never apply semiotics in UI design and evaluation. However, we made some changes to our framework, e.g., the 'umwelt level' was renamed as 'environment level', 'de-notational meaning, is replaced by 'correct meaning', and other terms are defined and discussed with suitable examples, to make them more clear and understandable.

D2. Insufficient learning resources – Six participants mentioned that insufficient material was provided to learn to apply the framework in real cases. Some of the evaluators mentioned that some of the concepts of the SIDE framework need to be explained in greater detail, with more examples. Others mentioned that the short training was not sufficient to understand the framework properly. One expert responded *"...Maybe some kind of 'book of examples' could be used to aid the user of the framework…"* If we look at the profiles of the participants (e.g., their expertise, familiarity with semiotics theory) and the broadness of the SIDE framework (e.g., number of aspects considered for interface sign design and evaluation), we do agree that a short tutorial (3 hours) is not sufficient to discuss the SIDE framework in detail, with examples, which means that this result is not surprising. This drawback is also related to D3 and D5, where participants stated that the hierarchical depth of the SIDE framework is complex, and that learning to apply the framework is time-consuming, i.e., insufficient learning resources are one of the main reasons why participants experienced difficulties.

D3. Complex hierarchical depth – one participant from each group mentioned that the hierarchical depth of the SIDE framework is complex and sometime confusing. They mentioned the following issues: (a) some terms (i.e., determinants and attributes) overlap, even though they belong to different levels, e.g., 'Position' is a determinant at the syntactic level and 'sign location' is a determinant at the pragmatic level of the SIDE framework; (b) a terminology is used as determinant and also as an attribute, even though it belongs to different levels, e.g., 'color' is a determinant at the syntactic level, and it is also used as an attribute for 'cultural marker' at the social level; and (b) some terminologies are difficult to differentiate from each other and belong to the same determinant at the social level, e.g., the attributes 'reality' and 'real-world objects' of the 'matching' determinant. We understand this problem and revised the framework to solve these issues by changing their hierarchical position, by removing the duplicate determinants, by changing the name of some terms and by defining some terms with suitable texts and examples.

D4. Excessive features – One novice and one expert mentioned that the framework includes too many features (determinants and attributes), which makes the framework difficult to learn and apply. One expert responded: *"….It is somewhat difficult to apply, as there are 50+ attributes that should be taken into account…."* This problem is related to problem D6, i.e., the framework takes too much time and effort, also due to the excessive number of features. This drawback is somehow contradictory to benefit B1, i.e., the broadness of the framework. Although this problem is quite understandable, we still see this as a positive sign, because the attributes and determinants are derived from the empirical data and because the participants like the broadness of the framework, as discussed in B1.

D5. Too structured – One intermediate evaluator and two experts mentioned that the framework is too structured and prescriptive. They stated that it is somewhat difficult to analyze the interface signs systematically, layer by layer, for each and every determinant. One expert responded: *"…Too structured and prescriptive to be practical in real commercial projects…."* We asked our evaluators to follow a systematic path to analyze the interface signs at all levels of the SIDE framework, and also to write the evaluation report in a structured way, for the following reasons: (i) the purpose of this study was to assess the quality and applicability of the framework, (ii) the students, who had little experience with UI design and evaluation, were recruited voluntarily as test-participants (evaluators), and (iii) evaluators evaluated the interface signs by considering all the features of the SIDE framework in a systematic way. We understand the concerns expressed by the evaluators when it comes to real commercial projects. This drawback is also related to D6, because systematic evaluation took too much time. However, in practice, professionals can first learn to use the framework precisely, and then they can use the heuristics (i.e., the SIDE framework) in a more general way, like the way heuristics are used in a heuristic evaluation method to assess usability. In other words, professionals should target the 'interpretation accuracy' (the attribute of semantic level) in their mind (i.e., step 2.1 of table 3), and other attributes of other levels should be used to evaluate the signs and assess the intuitiveness of interface signs, and to find the problems related to the intuitiveness of interface sign (i.e., step 2.2 – 2.4 of table 3). One expert responded: *"…. I am not sure if the structure is OK – for evaluation maybe, but otherwise maybe less… In practice, 'Interpretation accuracy' is actually what matters and it is the attribute we should be able to improve or explain (independent variable that is explained by other variables)…"*

D6. It costs time and effort – Four evaluators and one expert mentioned that it takes a lot of time and effort to learn to apply the framework. Based on their responses, we identified the following reasons: (a) the framework includes too many new features or concepts, (b) the training that was provided was too short, (c) insufficient learning materials (e.g., there is a need for more example to explain some concepts of the SIDE framework), (d) the profiles of the evaluators (i.e., a little experience with UI design and evaluation), and (e) the detailed instructions regarding the evaluation and the subsequent evaluation report. This drawback is related to some of the other drawbacks mentioned above. If we look at the profiles of the evaluators and the broadness of the framework, this drawback is understandable. One intermediate evaluator responded: *"…. It takes quite a lot of time to learn this framework by heart. I had to look up every single heuristic every time for every sign at every level of evaluation…."*, while another evaluator stated: *"…Quite time-consuming to apply the framework. But not too difficult, once I started remembering the values (attributes) of determinants or heuristics …."* However, the following

activities may reduce this drawback: (i) provide understandable terminologies, (ii) provide more suitable examples to explain the attributes of the framework, (iii) prescribe a less structured approach to evaluating and to writing the evaluation report, (iv) refine the categorization of determinants and attributes in the SIDE framework, to overcome the complexity with hierarchical depth and (v) provide more extensive training (e.g., a full day tutorial).

5. Discussion

It is difficult to compare and justify the outcomes of different performance evaluation studies, because they vary on aspects, related to the study set-up, participant or evaluator profiles, evaluation aims and analytical approach. However, to give an overall impression of the relative quality of the SIDE framework, we briefly discuss the results of other related studies.

Table 8. A comparative view of results of SIDE framework with other related studies

Other tools / techniques	Results of other studies	Results of the SIDE framework
W-SIDE (Speroni et al., 2006; Speroni, 2006)	a) Accurately detected problems: 90% b) False positive: 35% c) False Positive (after refinement):16%-14%	a) Accurately detected: 67% (novice); 80% (intermediates) ; & 72% (all) b) False positive: 33% (novice); 22% (intermediate); & 29% (all)
MiLE+ (Bolchini & Garzotto, 2007)	a) Accurately detected: 35% b) Learning time: 10-13 hours	a) Accurately detected: 67% (novice); 80% (intermediates); & 72% (all) b) Learning time: 4-6 hours (novice); 3-5 hours (intermediates) ; & 3-6 hours (all)
SEEM (Bekker et al., 2008)	a) Thoroughness (mean, SD): 0.26, 0.10 b) Validity (mean, SD): 0.68, 0.13 c) Appropriateness: 75%	a) Thoroughness (mean, SD): 0.58,0.17 (novice); 0.78, 0.10 (intermediate); & 0.66, 0.18 (all) b) Validity (mean, SD): 0.67,0.19 (novice); 0.80, 0.14 (intermediate); & 0.72, 0.19 (all) c) Appropriateness: 51% (novice); 70% (intermediate); & 58% (all)

Speroni et al. (2006) tested the effectiveness of W-SIDE framework (Speroni, 2006) in terms of evaluating the web interfaces. Their results show that expert inspection accurately detects about 90% of the problems, and 35% detected problems were false positive. After refining their inspection technique, they succeed to reduce the false positive to 16% -14%. Whereas the results of our study show a comparatively low value (see table 8), for example, intermediate evaluators detect about 80% of the problems accurately and 22% of the detected problems are

false positives. However, there are few observable issues related to the study set-up, participants' or evaluators' profiles, which explain differences in results. The issues are:

i) In case of the W-SIDE framework, the expert inspection was carried out by a group of experts including the authors of the W-SIDE framework (Speroni, 2006; Speroni et al., 2006). In case of the SIDE framework, expert inspection was carried out by student evaluators, who have limited experience with UI design and evaluation, and no experience in semiotics. Moreover, in our study the expert inspection is carried out individually, not by a group of evaluators.
ii) The web user interfaces considered in the W-SIDE study, the test-set up and the data analysis approaches were different.
iii) Since a group of experts, including the authors of the W-SIDE framework, carry out the inspection study, we can assume that the *appropriateness* of applying the heuristics of W-SIDE was 100% in their study. Our results show that the *appropriateness* of novice and intermediate evaluators was 50 % and 70%, respectively, and that they detected, on average, about 67% and 80% problem accurately (see table 8).

Bolchini & Garzotto (2007) measured the quality of MiLE+ with graduate students. A usability evaluation method integrated the concept of semiotics. Their results showed that each evaluator accurately detected about 35% problems and took about 10-13 hours to learn the MiLE+. Again, Bekker et al. (2008) carried out a study to verify the quality of an evaluation method (Structured Expert Evaluation Method – SEEM) with students. Their results (mean and SD values) for each evaluator showed that *thoroughness*, *validity*, and *appropriateness* were 0.26 (0.10), 0.68 (0.13), and 75%, respectively. The results of our study show a comparatively good value (see table 8), for example, novice evaluators spend about 4-6 hours to learn the framework and still able to detect about 67% problems accurately; for intermediate evaluators *thoroughness*, *validity*, and *appropriateness* were 0.78 (0.10), 0.80 (0.14), and 70%, respectively (see table 4 and 5). Bolchini & Garzotto (2007) also suggested a hypothesis on *learnability* that 'if the effort needed by novice to study the method and to become able to carry on an inspection activity with a reasonable level of performance is less than 15 hours, then the results can be read positively' (Bolchini & Garzotto, 2007, p.487). Based on their hypothesis, our results *learnability* can be read quite positively. However, still there are few observable issues that explain differences in results, e.g., MiLE+ and SEEM focus on all usability issues of a system (e.g., navigational structure, information architecture, layout, etc.), not only on the interface signs, like the SIDE framework; the participants' profiles, teaching duration, studied applications, etc. were also different in each study set-up time.

Reis & Prates (2013) assessed the cost, benefits, advantages and disadvantages of the semiotic inspection method (SIM). They found that the SIM is quite useful for thoroughly evaluating a system's communicability. They also found that the SIM is difficulty to learn and apply, one of the main reason being that it is built on semiotics theory (i.e., Semiotic engineering) and evaluators need to learn the underlying theory first to understand the SIM. We also obtain these kinds of results when participants are agree that the SIDE framework is useful for designing and evaluating the interface signs, but it takes too much time and effort to learn and apply the SIDE framework in a precise way.

On the discussion presented above, if we consider the results of other usability inspection studies that are developed as a new approach or framework, and if we consider the profiles of our participants and the testing conditions, our results with regard to the performance metrics are quite acceptable.

The main drawback of the SIDE framework is that it costs a lot of time and effort to learn to use the framework in evaluating interface signs, because (i) the framework is based on the semiotics concepts and includes large number of features from a semiotics perspective; (ii) provides limited learning resources; and (iii) follows an approach that is too structured. In addition, the knowledge and skills needed to learn to use a semiotics-based framework and carry out any usability inspection takes a lot of time and effort; because (a) the evaluators were not familiar with the concept of semiotics, and (b) the novice and intermediate evaluators were students having little experience with interface design and usability evaluation.

The main benefit as mentioned by the participants is that the SIDE framework is detailed and covers every aspects related to design and evaluate the interface signs to make them intuitive for end-users. The framework provides sufficient details to gain underlying knowledge or concepts in order to assess intuitiveness of interface signs, to detect the problems of interface signs, to design/redesign the interface signs to make them more intuitive for end-users, and to improve web usability.

5.1. Implications for Practice

The results of this study provide important suggestions from a semiotics perspective for a tool to understand user interface design and web usability evaluation. The results have important practical implications. *First*, the results give practitioners an awareness of the importance of user-intuitive interface signs. *Second*, the results show that the SIDE framework will advance the knowledge for designing user-intuitive interface signs and improving website usability. Finally, for practitioners, the results may play a major role in user interface design and evaluation, in the following ways: (a) it raises awareness of semiotics concept, (b) assists in interface sign design choice, (c) provides support for interface sign evaluation, either by an expert inspection or user tests, and (d) provides support for making interface signs intuitive to end-users.

Moreover, it is worth to mention that the SIDE framework is not developed for replacing or competing the existing non-semiotic work (e.g., Neilsen's (1995) guidelines, Shneiderman's (1987) guidelines) developed to design web interfaces as a whole. The SIDE framework, as a whole is an artefact and is completely different from any other existing non-semiotic work on web design and evaluation. The SIDE framework is developed to provide valuable insights to design and evaluate only interface signs, and do not focuses on other design dimensions like information architecture, content, navigation structure, etc. (see figure 2). The SIDE framework thus will act as an additional toolkit with the existing non-semiotic works to design and evaluate web interfaces as a whole. For example, in a broader sense, a few semiotic guidelines of the

SIDE framework might be treated as corresponding to some existing non-semiotic work on web design and evaluation. For example, a semiotic heuristic ('make effective use of ontological guidelines in interface sign design') of environment layer corresponds to Nielsen & Mack's (1994) heuristic on 'match between system and the real world'. Nielsen (1995) describes this guideline as 'The system should speak the users' language, with words, phrases and concepts familiar to the user'. The SIDE framework will provide deeper knowledge to support UI practitioner in order to follow this guideline more efficiently and effectively. For instance, the SIDE framework helps to understand what kind of presupposed knowledge (or ontologies) are used to interpret the meaning of web interface signs, how the ontologies conflict and multiple ontologies impact the understanding of the meaning of interface signs, what kind of ontological signs are difficult to interpret, how practitioners can model users' profile based on their familiarity with different kind of ontologies, how practitioners can design and evaluate interface signs based on users' profile (i.e., users familiarity with different kinds of ontology), etc. Thus, our results of environment level of the SIDE framework will provide a deeper understanding to apply this existing heuristic, and obviously only to the dimension of 'interface sign' design of web design and evaluation. Moreover, Scolari (2009) suggests that a combination of semiotic and narrative methodology can open up new aspects of usability and HCI processes that will complement traditional approaches. Thus, integrating the SIDE framework with other usability evaluation methods (e.g., heuristic evaluation methods, laboratory based usability testing methods, user interviews, etc.) will provide additional value for the usability evaluation process. Integration could be carried out in several ways: (a) consider the SIDE framework as a tool kit to plan and conduct the usability test, and also to analyze the test data; (b) conduct a sign test followed by a usability test, then analyze the data of sign test based on the SIDE framework, and finally analyze the data of the usability test with respect to the findings of the sign test; or (c) use the semiotic heuristics of the SIDE framework as a tool kit integrated with other heuristics (e.g., Nielsen's (1995) set of heuristics) to evaluate the user interfaces.

5.2. Limitations and Implications for Future Research

The study has limitations that need to be acknowledged and that can be viewed as areas for future research. First, the qualitative data (participants' responses in *Study I* and answers of open-ended questions of *Study II*) of this study were analyzed only by the first author. The analysis of qualitative data is generally subjective as it depends on people's knowledge, assumptions, and inferences. However to avoid bias in the analysis, the results were discussed with experts and a review process was also carried out. Second, only the novice and intermediate evaluators used the SIDE framework to evaluate the given sample of interface signs and the expert evaluators gave their subjective feedback based on their expertise. However, although we remain confident that our results are effective, useful and reliable, it may prove worthwhile to validate the results by using the framework in real cases by experts/ practitioners.

Finally, the study also helps to point several avenues for future research. Some future works include, but are not limited to: (a) whether the initial cost related to time and effort decays over

a longer period of time; (b) the SIDE framework was developed mainly for desktop based web user interfaces; and in this study the expert inspection was carried out by considering the web interface signs, thus it is not clear how much the SIDE framework may offer, what limitations may arise, and what specific semiotic heuristics or determinants are needed to apply the SIDE framework on mobile user interfaces where signs have an even more importance; and (c) assessing the impact of the SIDE framework on the performance of usability evaluation either by integrating the heuristics of the SIDE framework with other heuristics (e.g., Nielsen's (1995) set of heuristics) or by integrating the SIDE framework as a tool kit with other usability evaluation approaches (e.g., user tests).

To conclude, the findings that we have presented show that the SIDE framework is applicable for designing and evaluating the web interface signs and making them intuitive for end-users. Based on our findings, the SIDE framework has already been refined by considering the following activities, to reduce the observed drawbacks to a certain extent: providing understandable terminologies and more suitable examples to explain the attributes of the framework, using a less structured approach to carry out the evaluation process, renaming some determinants and attributes, and refining the categorization of determinants and attributes in the SIDE framework. Our future plan is, firstly, to carry out a study by integrating the SIDE framework into any usability evaluation method, to assess its impact on performance of overall usability evaluation, and, secondly, to apply the framework in mobile user interfaces, to assess and update the framework for designing and evaluating the interfaces signs of mobile user interfaces.

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Appendix I

Briefly present the semiotic heuristic of the SIDE framework.

Table A1. The semiotic heuristics of the SIDE framework

	Determinants	**Semiotic heuristics**
Syntactic	Interactivity	SH1. Clearly present the purpose of interactivity (e.g., whether a sign designed for an interactive purposes or only for a decorative purpose) *i) through the color, label, position, underlining, font size or a small arrow for/with the sign;*
	Color	SH2. Making effective use of color to design an interface sign *i) keep the original brand color,* *ii) use the sign color properly to provide its interactivity indication;* *iii) make effective uses of sign color to focus a sign and its importance in an UI;* *iv) keep the original color to reflect the pictorial reality with the real-world object;* *v) provide high contrast between the background color and the*

		sign color; *vi) use the lightness of sign color properly;*
	Clarity and readability	SH3. Make the representamen readable and clearly noticeable *i) make the representamen visible and clearly noticeable;* *ii) do not use distracting signs;* *iii) make interface signs with different objects look different;* *iv) avoid overlapping words in the sign label;* *v) avoid creating an interface sign that is buried with the text;* *vi) create the signs in a concise and expressive way;* *vii) avoid obscureness in sign design;* *viii) avoid placing an interface sign too close to other signs that are not thematically or functionally similar;* *ix) reduce noticeable distances between related interface signs (e.g., distance between an interface sign and its indicative sign or text);*
	Presentational aspects	SH4. Make a sign presentation clear and concise *i) use concise and self-expressive text as a sign label;* *ii) use shortened texts that are common in the real world as sign labels;* *iii) use acronyms that are common in the IT world as sign label;* *iv) design pictorial signs for referential meaning based on what they look like;* *v) show reality in designing pictorial signs;* *vi) design the sign structure (e.g., font size, size of text boxes, etc.) properly;*
	Representamen context	SH5. Create the representamen context appropriately *i) show the name of the web domain and website to the end-users;* *ii) give a clear indication of the current page, page title, the purpose of the page, etc.*
	Consistency	SH6. Follow a consistent interface sign design strategy *i) follow a uniform design strategy in designing the interface signs for a particular web application;*
Pragmatic	Sign Location	SH1. Place the representamen at the proper position in a UI *place an interface sign at a UI so that –* *i) the place matches the users' habit of using the same kind of sign at the same location;* *ii) most of the website belongs to a particular web domain that uses the same location for a particular sign;* *iii) interface sign attracts user attention;* *iv) appropriate neighboring or surrounding signs are present;*
	Amplification	SH2. Make effective use of amplification features in interface sign

		design *i) append meaningful small images or thumbnails with linguistic signs;* *ii) provide effective small text descriptions with interface signs;* *iii) append an appropriate icon with the linguistic sign;* *iv) append effective small text as an indicative sign with an interface sign;* *v) append acronyms with linguistic signs;*
	Relations	SH3. Create good relations among the interface signs of a UI *i) design interface signs so that they have paradigmatic relations with other interface signs in a UI;* *ii) place the interface signs with neighboring signs that belong to the same paradigm;* *iii) maintain the syntactic relationships among interfaces signs in a UI;* *iv) maintain concurrent relations among interface signs in a UI;* *v) maintain dependency relations among interface signs in a UI;* *vi) design the interface signs in a UI so that the end user can easily notice and understand the relations (paradigmatic, syntactic, concurrence, and dependence) among them.*
	Coherence	SH4. Retain the logical coherence in Interface sign design *i) design interface signs that are logically coherent in the meaning of the sign and real world facts.*
Social	Cultural marker	SH1. Design interface signs to be culturally sensitive or reactive, when necessary *An application may be developed for a very specific cultural context or be universally accessible. Depending on the application's objectives and the focus on the end-users, the interface sign should build on some principles:* *i) use appropriate sign colors to reflect the meaning of the interface sign in its cultural context;* *ii) use or avoid local cultural slang or terminology as sign labels;* *iii) use or avoid critical cultural icons or images in interface sign design; use language in interface sign design that is commonly understandable to the intended users.*
	Matching	SH2. Matches the reality, conventions, or real-world objects *i) follow some underlying reality;* *ii) follow the conventions in interface sign design;* *iii) build on matches with real-world objects;*
	Organization	SH3. Make an effective use of organizational features in interface sign *i) In some cases, an organization's category, name, and products or services help end-users understand the meaning of a sign in*

		web UI. Thus, designing interface sign with support from these properties may improve the intuitiveness of the sign for the end-users.
	Mapping	SH4. Mapping with metaphorical and attributing properties *i) use metaphorical mapping in interface sign design;* *ii) use of attributing mapping in interface sign design;* *iii) use mapping properties to reduce conflicting interpretations*
Environment	Ontology	SH1. Modeling the profiles of the focused end-users *i) Modeling the user profile based on how familiar they are with an ontology will assist practitioners to design and evaluate user-intuitive interface signs. For example, for a particular application the focused user group's profile can be as follows: Internet Ontology: high; Website Ontology: low; Current Web Domain Ontology: high; Other Web Domain Ontology: average; Common-sense Ontology: high; System Ontology: average; Computer Ontology: high, Mobile Ontology: high; Institutional Ontology: average; Real World Ontology: high; Cultural Ontology: average. Then, the focused end-users familiarity with ontologies will assist practitioners to design and evaluate user-intuitive interface signs.*
		SH2. Make effective use of ontological guidelines in interface sign design *i) design the interface sign based on users' familiarity level with ontologies;* *ii)create interface sign to avoid ontology conflict;* *iii) design interface signs that is belong to multiple ontologies;* *iv) avoid creating interface signs that belong only to the 'Website Ontology',* *(re)design interface signs which belong to ontologies, with whom user experienced a lower level of perceived difficulty (e.g., Internet Ontology);*
Semantic	Interpretation accuracy	SH1. Design an interface sign in such a way as to make sure end-users understand its meaning *i) The principles of semiotics theories in UI design suggest that a user's interpretation should matches with the designer's interpretation. Thus, examine the level of accuracy of users' interpretation of an interface sign and follow the properties of other semiotic layers to (re)design interface signs, so that end-users can easily understand their meanings accurately (i.e., look up the interface signs in the other levels of the framework).*

Appendix II

The equations to measure the performance metrics:

$$Thoroughness = \frac{number\ of\ \ real\ \ problems\ identified}{number\ of\ \ real\ \ problems\ that\ exist}$$

$$Validity\ = \frac{number\ of\ \ real\ \ problems\ identified}{number\ of\ \ problems\ identified}$$

$$Effectiven\,ess = Thoroughness \times Validity$$

$$\text{Re}liability\ = Maximum\ \left\{0, \left(1 - \frac{stdev\ (number\ of\ \ real\ \ problems\ identified}{average\ (number\ of\ \ real\ \ problems\ identified}\right)\right\}$$

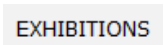
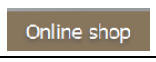
$$Effeciency\ = \frac{number\ of\ \ real\ \ problems\ identified}{Total\ \ evaluation\ \ \ time}$$

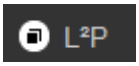
$$Accuracy = \frac{number\ of\ \ sign'\,s\ \text{int}uitiveness\ \ \ level\ identified\ \ correctly}{Total\ number\ \ \ of\ \ evaluated\ \text{int}\ erface\ signs}$$

$$Appropriateness = \frac{Number\ of\ \ heuristics\ or\ guidelines\ \ applied\ \ correctly}{Total\ number\ of\ \ heuristics\ or\ guidelines\ \ applied}$$

Appendix III

Table A3. The semiotic heuristics of the SIDE framework

Sign	Intuitiveness	Problems
	High	
	Less	• The purpose of interactivity is not present clearly • Do not append any amplification feature • Do not retain the logical coherence in interface sign design • Do not match with interface sign conventions • The sign is belong to website ontology • The sign create ontology conflict
	High	
	High	
	Less	• Relations with neighbor signs was not present clearly • The text of the sign is culturally sensitive (not commonly

		understandable as the text comes from Greek) • The sign belongs to ontologies (e.g., current web domain ontology, cultural ontology, website ontology), with whom users were not highly familiar.
	Less	• Provide the low contrast between the background color and the sign color • Do not follow consistent design strategy with other signs of this page • Do not append any amplification feature (e.g., append icon like >>, …) • The sign text is not written in English • The sign is belong to cultural ontology and website ontology
	High	
	Moderate	• Do not match with interface sign conventions • The sign crate ontology conflict (e.g., the word ‘range’ is confusing that refers to multiple meaning)
	Moderate	• The purpose of interactivity is not present clearly • Do not append any amplification feature (e.g., append copyright symbol, or the designation of photographer)
	High	• The appended icon create confusion (e.g., icon of graduation hat lead to interpret the sign as for alumni students) • The sign create ontology conflict
	Moderate	• The purpose of interactivity is not present clearly (e.g., users interpret this sign as search box) • The color of sing-text is not used in an effective way as it create confusion • The sign is not placed at a proper position (i.e., placed at noticeable distance from the related neighbor signs) • The layout of this sign is not designed properly (e.g., layout looks like a search box) • Do not append any amplification feature (e.g., append a dropdown icon) • The sign is belong to website ontology • The sign create ontology conflict
	Less	• The sign is not readable • The sign used acronym which is not common in IT world • Do not follow a consistent design strategy with neighbor signs • Do not append any amplification feature • The sign is belong to website ontology

Appendix IV

The data was collected using the following optional open-ended questions:

- What do you like most about the proposed framework? (16 responses)
- What do you like least about the proposed framework? (15 responses)
- Do you have any suggestion to improve the proposed framework? (12 responses)
- Please comment on the procedural guidelines to evaluate the interface signs. (11 responses)
- Any other comments on the proposed framework. (7 responses)

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