A Semiotic-informed Approach to Interface Guidelines for Mobile Applications

A Case Study on Phenology Data Acquisition

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Abstract: Portable devices have been experimented for data acquisition in different domains, e.g., logistics and census data acquisition. Nevertheless, their large-scale adoption depends on the development of effective applications with a careful interaction design. In this paper, we revisit existing interface design strategies and propose a guideline composed of semiotic-informed rules and questions for mobile user interface design. We demonstrate the use of the guideline in the evaluation of mobile application interfaces proposed for phenological data acquisition in the field.

1 INTRODUCTION

Portable devices have been adopted in different domains to support data acquisition (Abdallah, 2012; Hao et al., 2011; Podnar Zarko et al., 2013). Key motivations for their use rely on the associated low costs, recent improvements in the hardware robustness, the incorporation of different sensors (e.g., for location, audio, image, and video acquisition) that provide useful contextual information for different purposes, and the availability of easy-to-use frameworks for developing applications.

However, the effective adoption of portable devices depends on the use of applications with careful interface design. An appropriate design should be associated with reduced mental and physical stress, reduced learning curve, and improved device operability (Duh et al., 2006). The design and implementation of such interfaces deal with many constraints: small-size screens, data entry models, connectivity issues, and limited resources. Moreover, there are other factors underlying the user-system interaction that should also be considered, such as the social implications of changing work practices. In this sense, the definition and use of appropriate interface design guidelines may help application developers to address part of these challenges.

Information and Communication Technology has evolved rapidly, shaping our relationships in the world (e.g., economic, social, laboral, interpersonal, and ethical). The relationship between people and information is changing at the same pace, mediated by that technology. Within this scenario, and as part of it, designing or evaluating an application demands a systemic view on the prospective product of that technology. For this systemic view on the design of computer-based applications, Organizational Semiotics (OS) (Liu, 2000) has been a fundamental theoretical frame of reference for our work.

By making use of several design cues, indicators, and signs, Semiotics, the doctrine of signs, enables us to search for a more accurate understanding of information as properties of signs. Anything that stands for another or is used to mean something to someone is an example of sign: words, sentences, traffic lights, diagrams, a wave, a facial expression. Adopting Baranauskas' perspective to design (Baranauskas, 2013; Baranauskas, 2014), we take Semiotics beyond the study of how we use signs to communicate, to include shared knowledge and mutual commitment that establishes communication in the design process. In this sense, information, understood as signs, could be

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operated in distinct levels, meaning different operations a person can do upon the sign. These levels are represented as steps of a Semiotic Ladder (SL), or views of a semiotic framework (Stamper, 1973).

In this paper, we revisit existing interface design strategies and use the Semiotic Ladder from OS as an artifact to organize guidelines for the evaluation of mobile user interfaces. To the best of our knowledge, this is the first attempt to categorize existing guidelines according to the OS principles. The final guideline proposed, composed of 27 rules, is expected to support mobile interface designers and developers in their daily evaluation tasks. In order to illustrate that, we demonstrate the use of the final guideline in the evaluation of interfaces for mobile applications recently proposed in the e-Science domain. In these applications, we are interested in supporting data acquisition upon plant phenology in the field.

Plant phenology concerns the study of recurrent life cycles events and its relationship to climate (Schwartz, 2013). This discipline has been recognized as an strategic approach to climate change research (Schwartz, 2013). Plant phenology studies are based on a well-defined methodology that has as main objective the identification and understanding of temporal changes in reproductive or vegetative events (Morellato et al., 2010). Plant phenology studies depends, therefore, on the continuous acquisition and analysis of data over time. Usually, plants are observed directly in the field, and the phenophases defined by the investigators (e.g., flower, fruiting, leaf flush) are visually identified and registered on paper sheets on the field. This task is time consuming and error prone. These issues have motivated the investigation upon the use of portable devices to support the phenological data acquisition process.

The remaining of this text is organized as follows. Section 2 provides the background on related topics. Section 3 introduces the proposed semiotic-informed guidelines for evaluating mobile application interfaces, while Section 4 describes a case study concerning the use of the proposed guidelines in the evaluation of application interfaces proposed for phenological data acquisition. Finally, Section 5 presents our conclusions and directions for future work.

2 BACKGROUND

The definition of an appropriate guideline for mobile interface design was based on the identification of existing research in the area. Table 1 illustrates some relevant work in the literature, without exhausting the subject. The literature studies point to different aspects that are relevant in evaluating mobile application user interfaces. In this work, we select and refine guidelines, rules, and questions proposed in those studies, classifying them according to the different semiotic layers.

The Semiotic Ladder (SL) consists of six steps representing views on signs from the perspective of the physical world, empirics, syntactics, semantics, pragmatics, and the social world. The physical, empirics, and the social world are Stamper's (Stamper, 1973) contribution upon the traditional semiotic approach.

The *Social World* is the layer in which we analyze the consequences of the use of signs in human activities. It deals for example with beliefs, expectations, commitments, law, and culture. *Pragmatics* is the layer studying the intentional use of signs and behavior of agents. Issues related to the intention and negotiation are objects of the pragmatic. *Semantics* deals with the relationship between a sign and what it refers to (its meaning); signs in all modes of signification. *Syntactics* deals with the combination of signs without considering their specific meaning. *Empirics* deals with the static properties of signs, when media and different physical devices are used. Finally, *Physical World* works with the physical aspects of signs and their marks (e.g., infrastructure issues).

In summary, the top three steps of the SL are related to the use of signs, how they work in communicating meanings and intentions, and the social consequences of their use. The three lower steps, in turn, answer questions related to how signs are structured and used, how they are organized and conveyed, and what physical properties they have, among others.

In the context of our study, the SL is an artifact that has been adapted for organizing the guidelines for system evaluation, covering aspects from its technological infrastructure (physical world, empirics, syntactic layer) to the system of human information (semantic layer, pragmatics, and social world). Therefore, this artifact supports both a wide and deep view of the different aspects that may be considered when evaluating interfaces for mobile devices. Other uses of the SL in different domains can be found in the literature, such as (Piccolo and Baranauskas, 2013).

3 PROPOSED GUIDELINE

From the analysis of literature concerning the evaluation of portable device applications based on publications associated with ACM and IEEE conferences and journals (see Table 1), we classified existing guidelines, rules, and questions according to the Semiotic

Table 1: Literature overview on mobile interface design.

References	Overview
(Nayebi et al., 2012)	- can be considered the state-of-the-art work concerning the evaluation of the usability of mobile applications; - presents a methodology for usability evaluation; - suggests that there is little scientific research in this area.
(Radio et al., 2012)	- presents guidelines based on the latest research in industry and academia; - addresses search design and development of successful mobile applications that can utilize the capabilities of next generation cellular network; - presents a model for developing client-server applications based on 4G technologies.
(Zamzami and Mahmud, 2012)	- states that there is little research focused on assessing the information quality on smartphone interfaces; - examines three main areas: mobile interface design, information quality, and user satisfaction.
(Rauch, 2011)	- discusses differences in usability research focused on desktops compared with what has been done for mobile devices; - summarizes emerging trends in usability studies for mobile devices; - suggests best practices for developing user assistance for mobile devices.
(Ayob et al., 2009)	- proposes a three-layer design model for mobile applications based on four existing guidelines.
(Hussain and Kutar, 2009)	- presents a usability metric framework for mobile phone applications; - proposes 10 factors that are subdivided into 26 criteria and 127 metrics; - is integrated to the ISO 9241.
(Ryu, 2005)	- presents usability questionnaires for electronic mobile products and decision making methods; - proposes an evaluation questionnaire containing 72 items.
(Gong and Tarasewich, 2004)	- presents guidelines for handheld mobile device interface design; - is based on golden rules of interface design.

Ladder.[1] This step generated a total of 147 guidelines, distributed as follows: 15 into Physical World; 10 into Empirics; 58 into Syntactics; 26 into Semantics; 20 into Pragmatics, and 18 into Social World.

A novel set of guidelines was defined by merging similar ones and by discarding those considered non-pertinent to the application domain (13 in total). Examples of removed guidelines include questions such as “Is it easy to change the ringer signal?”, “Is it easy to check missed calls?”, “Is it easy to check the last call?”, “Is it easy to send and receive short messages using this product?”, “Is it easy to use the phone book feature of this product?”, “Can you personalize ringer signals with this product?”.

Although those are general questions important to evaluate interaction and communication with the mobile device, they are not relevant for a mobile application interface evaluation in the domain considered. The resulting set included 7 guidelines into the Physical World, 9 into Empirics; 16 into Syntactics, 10 into Semantics, 28 into Pragmatics, and 9 into the Social World, totalizing 79 guidelines.

These guidelines and their classification were reevaluated and refined by 10 experts in the fields of OS and HCI, to eliminate redundancies and to come with more appropriate descriptions and a more cohesive set, resulting in a guideline composed of 27 rules distributed as follows: 4 into the Physical World, 4 into Empirics, 7 into Syntactics, 4 into Semantics, 5 in Pragmatics, and 3 into the Social World. Figure 1 illustrates the whole process for refining and organizing the guidelines. The final set of rules considered in the proposed is presented in Table 2.

Finally, a questionnaire was proposed to support the evaluation of mobile applications according to each defined rule. The proposed questionnaire is presented in Tables 3, 4, 5, 6, 7, and 8. Each table refers to a different SL step. Note also that, more than one question can be used for a particular rule in some cases. For example, for the fourth rule related to the Physical World (*“Create design suitable for small devices with touch screen”*) – see Table 2, two questions are defined for the evaluation process: *“Are pictures on the screen of satisfactory quality and size?”*; *“Does the application provide appropriate menu button for touch screen?”*.

For each question, the evaluator should indicate, in a Likert scale (from 1 to 5), whether the application is attending to the guidelines recommendations. In the scale: 1 means that the evaluator strongly disagrees; 2, disagrees; 3, neither agrees nor disagrees; 4, agrees; 5, strongly agrees.

[1]From now on, we will refer to this set as literature guidelines, or simply guidelines.

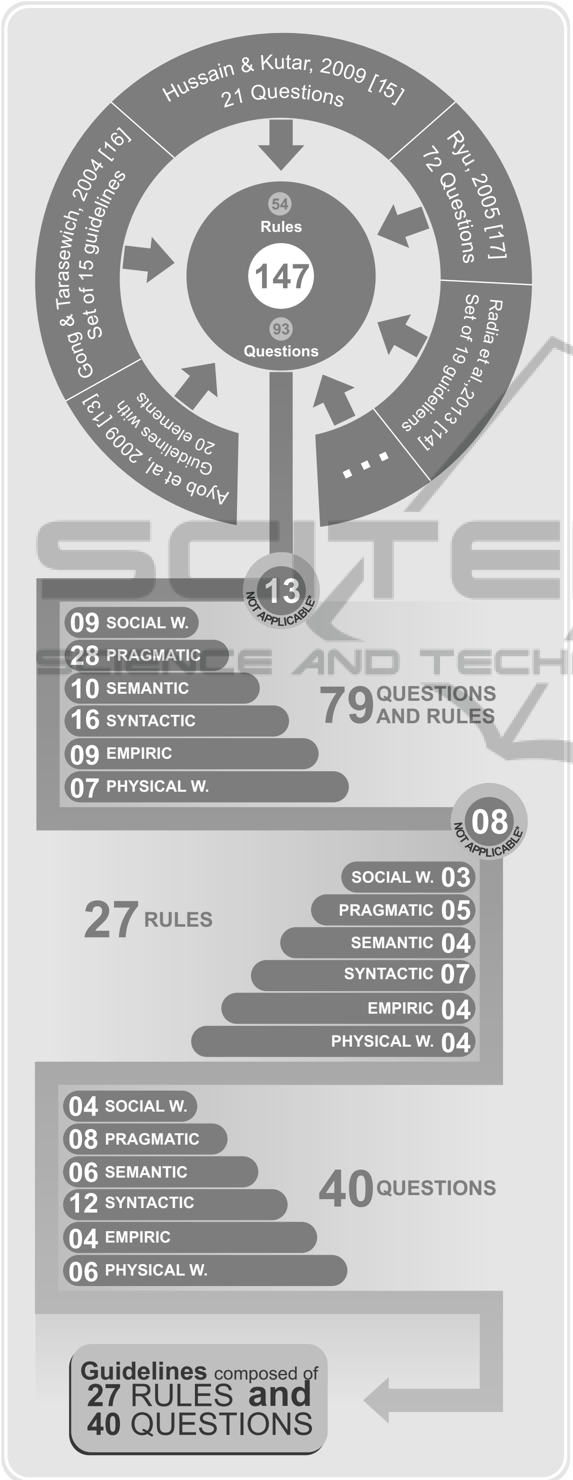

Figure 1: The guideline refinement process. The resulting set, composed of 27 rules, is presented in Table 2, while the 40 questions proposed to evaluate mobile interfaces according to the defined rules are presented in Tables 3–8.

Table 2: Proposed Guideline. This Guideline is composed of 27 rules.

Step on the Semiotic Ladder	Rule Description
Physical World	1 - Provide adequate contrast
	2 - Provide methods for easy and functional data entry
	3 - Create design suitable for small devices with touch screen
	4 - Easy operation with one hand
Empiric	5 - Implement planning on speedup
	6 - Keep recent data for reuse
	7 - Facilitate data exchange with other applications
	8 - Provide automatic application update
Syntactic	9 - Adequately provide information on system resources
	10 - Give control to the user of the application
	11 - Maintain consistency in the standards used both in data presentation as in how to perform each task
	12 - Facilitate the navigation between screens and information
	13 - Keep the user informed of what is happening through constant feedbacks
	14 - Provide shortcuts and wizards
	15 - Reduce mental efforts and memory requirements
Semantic	16 - Facilitate the discovery of new functionality
	17 - Provide output of data easy to use
	18 - Provide appropriate documentation by means of manuals and helps
	19 - Design clear and understandable interfaces
Pragmatic	20 - Design the application thinking about simplicity
	21 - Develop the application thinking in multiple contexts
	22 - Provide feedback to aid the prevention of errors and troubleshooting as well as provide means for reversing actions
	23 - Allow customization of the application by users
	24 - Facilitate application learning
Social World	25 - Implement security and privacy controls
	26 - Know your target audience in order to raise the application requirements, needs and “intrinsic” desires
	27 - Implement controls to avoid risks while using the application in motion (driving, walking, etc.)

4 CASE STUDY

This section presents conducted case study that aims to demonstrate the use of the proposed guideline. This case study concerns the evaluation of the interfaces of three prototypes designed to support the phenologi-

Table 3: Questionnarie Proposed - Physical World.

Rule	Question
1	Is the backlighting feature for the keyboard and screen appropriate in all contexts?
2	Does the application provide a virtual keypad? Does the application provide voice assistance?
3	Are pictures on the screen of satisfactory quality and size? Does the application provide appropriate menu button for touch screen?
4	Is it sufficiently easy to operate keys with one hand?

Table 4: Questionnarie Proposed - Empiric.

Rule	Question
5	Are the response time and information display fast enough?
6	Are data items kept short?
7	Are exchange and transmission of data between this product and other products (e.g., computer, PDA, and other mobile products) easy?
8	Does the application provide automatic update?

Table 5: Questionnarie Proposed - Syntactic.

Rule	Question
9	How much information about system resources was displayed?
10	Are the HOME and MENU buttons sufficiently easy to locate for all operations? Are the letter codes for the menu selection designed carefully?
11	Are the color coding and data display compatible with familiar conventions? Can all operations be carried out in a systematically similar way?
12	Is the organization of information on the product screen clear? Is it easy to navigate between hierarchical menus, pages, and screen?
13	Is feedback on the completion of tasks clear? Does application provide feedback (haptic, audio, visual, etc.) constantly in order to keep the user engaged and attentive?
14	Does application provide shortcuts for experienced users and wizards for new users?
15	Does interacting with this product require a lot of mental effort? Is it easy for you to remember how to perform tasks with this product?

cal data acquisition process in the field. We first describe the data acquisition process scenario in Section 4.1. Next, we describe the evaluated prototypes in Section 4.2. Finally, in Section 4.3, we present and discuss the results obtained from the evaluation using the guidelines.

Table 6: Questionnarie Proposed - Semantic.

Rule	Question
16	Is discovering new features sufficiently easy?
17	Is the output data easy to use?
18	Are the documentation and manual for this product sufficiently informative? Does the application provide appropriate help?
19	Is the interface with this product clear and underatandable? Is the design of the graphic symbols, icons and labels on the icons sufficiently relevant?

Table 7: Questionnarie Proposed - Pragmatic.

Rule	Question
20	Does this product enable the quick, effective, and economical performance of tasks? Is it easy to access the information that you need from the product?
21	Does application allow convenient use with the ability to handle multiple and frequent interruptions with limited attention from the user? Does design of application is suitable for multiple contexts (home, business, travel, etc.) including support for runtime adaptation?
22	Are the error messages effective in assisting you to fix problems? Are the messages aimed at prevent you from making mistakes adequate?
23	Does application provide the ability to personalize the application to suit the user?
24	Is it easy to learn to operate this product?

Table 8: Questionnarie Proposed - Social World.

Rule	Question
25	Does application allow privacy and security control for single or multiple users?
26	Does product have all the functions and capabilities you expect it to have? Is this product attractive and pleasing?
27	Is the application secure to use while driving or walking?

4.1 Phenology Data Acquisition in the Field

Recently, phenology has been recognized as an important discipline for understanding the impact of climate change on living beings (Menzel et al., 2006).

Phenology studies depend on the analysis of long-term temporal data (Newstrom et al., 1994). The common approach is the direct observation of plant individuals in the field at regular intervals (e.g., monthly or weekly) and the identification of phenophases (e.g., leafing, budding, flowering, ripening) (Morellato et al., 2000; Morellato et al., 2010). One widely

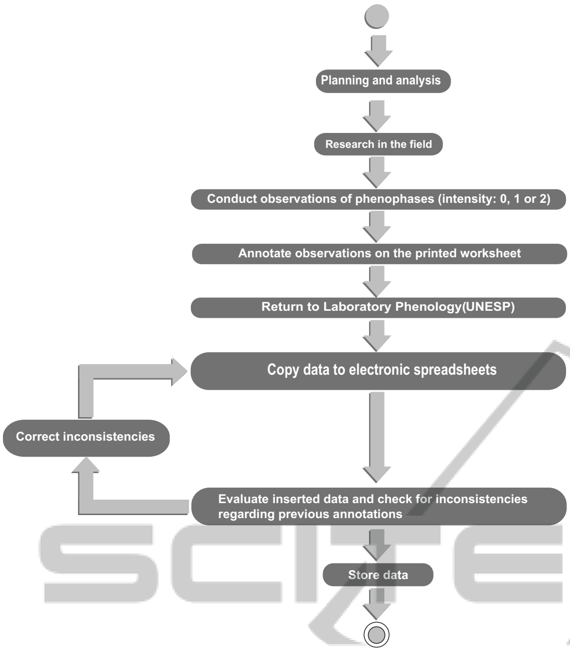

Figure 2: Typical data acquisition workflow.

adopted approach for data acquisition relies on using a qualitative method to assess the presence or absence of phenophase or using a quantitative method that assigns a different number (usually 0, 1, or 2) for a phenophase, depending on its intensity (d'Ea Neves and Morellato, 2004). Usually, phenophase intensities are registered on paper sheets (in the field) and later inserted into digital spreadsheets (in the laboratory). This acquisition procedure can lead to errors and discrepancies in the collected data, which can delay data processing and analysis, as well as knowledge discovery.

Figure 2 presents the typical phenological data acquisition workflow. First, on-the-ground observations are planned. Multiple phenology experts may be involved in this process. Next, the in-the-field observations are performed by assigning intensity scores to plant phenophases. These scores are then registered in paper worksheets. In the lab, these data are stored in digital spreadsheets. At this moment, inserted data are checked with the objective of determining any inconsistency with previous annotations. If any inconsistency is identified, spreadsheets need to be updated accordingly.

In this context, we have been specifying and developing new applications to support data acquisition in the field, based on the ongoing phenological observations carried out by the group from Phenology Lab at UNESP.[2] The objective is to design and implement applications for portable devices that may support phenology experts in the field by: i) providing location-aware information regarding plant individuals; ii) monitoring the evolution of the data acquisition process on real time; and iii) implementing intuitive and loss-free mechanisms for data insertion and validation. The main challenges faced here rely on both the design and the in-the-field validation of appropriate interfaces for data insertion using portable devices, as well as the implementation of protocols to guarantee that no data are lost in the whole data acquisition process. This paper addresses the interface design evaluation of developed prototypes using the proposed guideline.

4.2 Evaluated Prototypes

The prototypes of phenological data acquisition applications considered in this study were object of design within the scope of a graduate course in HCI (second semester of 2012) at the Institute of Computing, University of Campinas, Brazil. The methodology used in the design process was proposed based on recent studies of usability and inspired by Participatory Design practices and the Organizational Semiotics theory (Baranauskas, 2014).

The design problem proposed to the students involved the support to activities the biologists develop both in the lab (Planning and Analysis) and in the field (Field Work). The Planning and Analysis are activities in the lab to prepare the field work (pre-field), monitoring its execution, and analyzing data after field work (pos-field). Thus, the design problem involved (a) the design of a (web) application to support the planning of field work, and receiving and analyzing the data collected, and (b) the design of an application to support biologists in the field work. Both applications should communicate. The object of discussion in this paper is the mobile application to support the biologist field work.

A set of 25 students, organized in seven groups, worked in the role of designers to conceive and develop the interface of the application. Four groups designed mobile interfaces and three groups designed web applications for supporting the process management. All the groups conducted the following activities: i) problem clarification through participatory practices (e.g., Group Elicitation Method) and context analysis through Organizational Semiotics' artifacts (e.g., Stakeholder Identification Diagram, Evaluation Framework); ii) organization of a first set of

[2]Details from field site and sample methods can be found elsewhere (Camargo et al., 2011; Alberton et al., 2014).

(a) Prototype 1 (b) Prototype 2 (c) Prototype 3

Figure 3: Screen shots of evaluated prototypes.

requirements, prototyping (low and high fidelity) and evaluation in an iterative cycle.

During the process, the participants communicated with the partner biologists both online and in face-to-face meetings: from the very start when the problem was being clarified to the validation of requirements and the evaluation of different proposals. At the end of the term, the groups presented their prototypes to two biologists from the Phenology Laboratory, UNESP and two Computer Scientist from the Institute of Computing, University of Campinas. They were very excited with the great possibilities of the prospective applications to facilitate and add to their work in data acquisition in the field. Our challenge was then to evaluate these prototypes with a sound set of guidelines in order to discover which one (or what aspects of them) would best fit to the needs of experts within this domain (ePhenology Project).

The evaluation process considered three out of four prototypes. One of them was no ready for being evaluated at that moment. In Figure 3, we can see the screen shot of the prototypes considered in this evaluation. These screen shots refer to the main data acquisition procedure. In the first prototype, Figure 3(a), phenophase scores are defined using the "minus" (–) and the "plus" (+) buttons. In the second prototype, Figure 3(b), the scores are defined using a sliding bar for each phenophase. Finally, in the third prototype, Figure 3(c), a quite different design is adopted, where phenophase scores are represented by painted icons: When only one icon is filled (see for example the leaf fall phenophase – *Queda* in Portuguese), then the intensity assigned to this phenophase is 1. When two icons are filled (see for example the flower bud phenophase – *Botão* in Portuguese), the intensity assigned is 2.

4.3 Results and Analysis

To evaluate the prototypes with the proposed guideline, we invited a group of three specialists in HCI from the Institute of Computing, University of Campinas. For this evaluation, the proposed questionnaire was constructed from the guideline sentences and answered in a Likert scale (1-5). Based on the specialists' responses, we computed the average scores for each question. Figures 4, 5, 6, 7, 8, and 9 present these scores. Based on the evaluations, we highlight some important points:

- Regarding the Physical World step (see Figure 4), we can notice the high performance of all prototypes regarding Q2 ("The application provides a functional virtual keypad"). We can also observe low average scores of all evaluated prototypes regarding Q3 ("The application provides voice assistance"). Furthermore, it is worth mentioning the low performance of Prototype 2, with regard to Q4 ("The pictures on the screen are satisfactory quality and size") and the superior performance of Prototype 3 regarding Q5 ("The application provides appropriate menu button for touch screen").

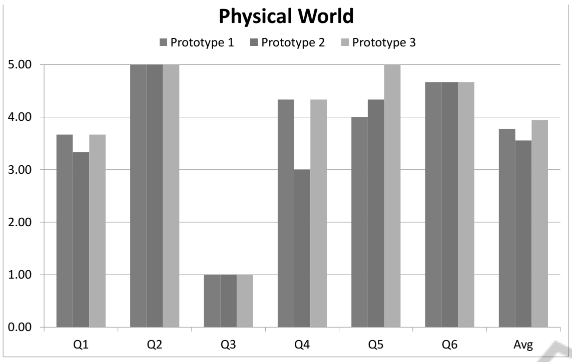

Figure 4: Average results for the Physical World step.

- Regarding the Empiric step (Figure 5), we can notice that all prototypes achieved high and low average scores for Q7 ("The response time and information display are fast enough") and Q10 ("Application provides automatic update"), respectively. It is worth mentioning the low scores for Q9 ("Exchange and transmission of data between this product and other products") observed for all prototypes, but for Prototype 2.

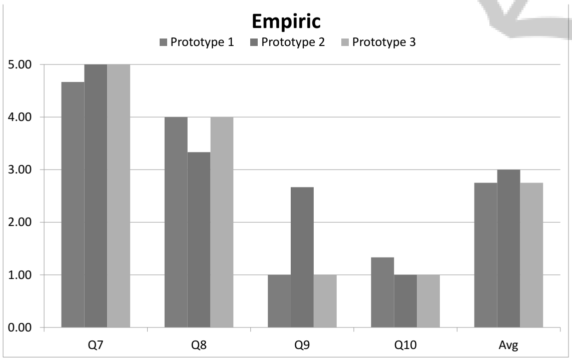

Figure 5: Average results for the Empiric step.

- Regarding the Syntactic step (Figure 6), we can observe that all prototypes have high scores, except for Prototype 1 in Q11 ("Enough information about system resources are displayed.") and Prototype 3 in Q13 ("Letter codes for the menu selection are designed carefully"). Another exception is Q20 ("The application provides shortcuts for experienced users and wizards for new users") which was neglected by all the prototypes.
- Regarding the Semantic step (Figure 7), we can observe that Prototype 2 is better than the other ones, except for Q28 ("The design of the graphic symbols, icons and labels on the icons are sufficiently relevant"), for which Prototype 3 is the best one. It is also worth mentioning the low scores observed for Q25 ("The documentation and manual for this application are sufficiently informative").

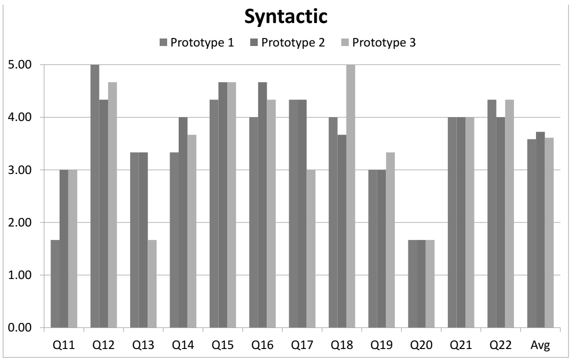

Figure 6: Average results for the Syntactic step.

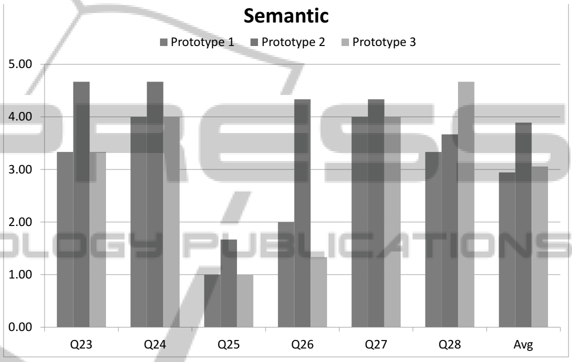

Figure 7: Average results for the Semantic step.

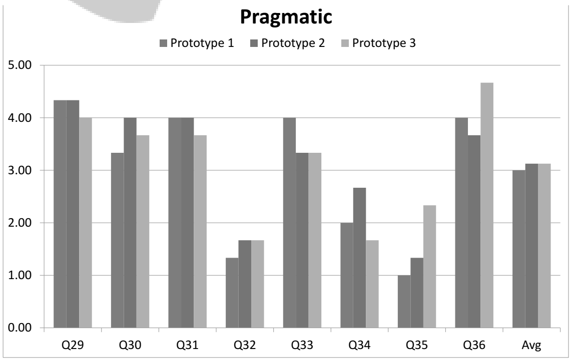

Figure 8: Average results for the Pragmatic step.

- Regarding the Pragmatic step (Figure 8), there is no clear winner, except for Prototype 1 in Q33 ("The error messages are effective in assisting you to fix problems") and Prototype 3 in Q36 ("It is easy to learn to work with this application"). It is worth mentioning the low scores observed for Q32 ("The design of application is suitable for multiple contexts including support for runtime adaptation"), Q34 ("The messages aimed at prevent you from making mistakes are adequate"), and Q35 (“The application provides the ability to personalize its enviroment to suit the user”).

- Regarding the Social World step (Figure 9), all prototypes need to be improved. We can observe, however, that Prototype 3 has the best score for Q39 (“This application is attractive and pleasing”).

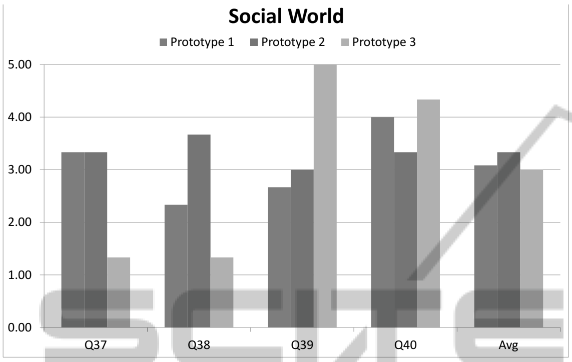

Figure 9: Average results for the Social World step.

Figure 10 shows the average scores for each Semiotic ladder step, considering its questions. As it can be observed, there is no clear winner prototype regarding all criteria. We can point out, however, that Prototype 2 is the best one in terms of the Empiric, Syntactic, Semantic, and Social World steps. In fact, its average score for questions related to the Semantic step is impressive.

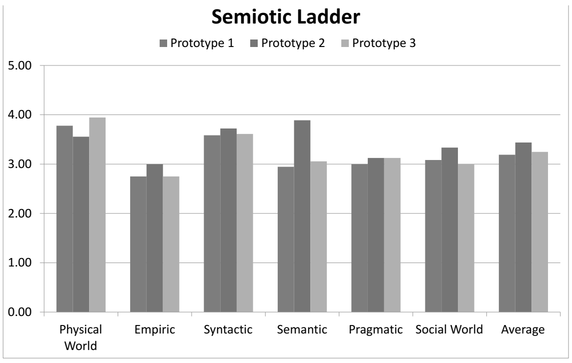

Figure 10: Average results for each Semiotic ladder step.

On the one hand, the results from the evaluation through the proposed guideline show that all the prototypes have interesting design decisions to be considered in the design of a final product. These results are even more important because they came from different design proposals that were created based on an informed and well-defined design process conducted by prospective designers in a Participatory style.

On the other hand, all the prototypes had been previously evaluated through other HCI evaluation techniques (e.g., Maedas’ Law of Simplicity, and Nielsen’s Heuristics) during the graduate course. Therefore, the results show that the proposed guideline supported designers in the identification of additional problems that may have go unnoticed in the previous evaluation, suggesting the guidelines’ usefulness to support the evaluation of mobile interfaces.

5 CONCLUSION

The large-scale adoption of portable device applications depends on the use of careful interface design. In this paper, we analyzed existing literature on guidelines, rules, and questions for portable device interface design under the semiotic ladder perspective, and proposed a novel guideline composed of 27 semiotic-informed rules for interface evaluation.

We demonstrate the use of the proposed guideline in the context of the evaluation of three prototypes recently proposed for phenological data acquisition. The analysis of results from evaluations indicates that the proposed guideline set is well suited for the evaluation of mobile application interface as it helps to identify positive and negative aspects of proposed designs, according to well-defined semiotic concepts of different information layers.

As future work, we intend to develop novel interface designs based on the findings related to the advantages and drawbacks identified in the evaluated prototypes, and to conduct experiments in which phenology experts will be able to evaluate the developed prototypes using the proposed guideline. Additionally, we are also planning to conduct further evaluation activities to assess the guideline’s contributions in different design contexts and with different groups of experts.

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