User-Centered Design and Evaluation – The Big Picture

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Abstract. This paper provides a high-level overview of the field of usability evaluation as context for a panel *"Systematization, Modeling and Quantitative Evaluation of Human Interface"* in which several authors report on a collaborative effort to apply CogTool, an automated usability evaluation method, to mobile phone interfaces and to assess whether usability predictions made by CogTool correlate with user subjective impressions of usability. If the endeavor, which is still underway at the time of writing, is successful, then CogTool may be applied economically within the product development lifecycle to reduce the risk of usability problems.

Keywords: Usability evaluation, methods, metrics, systematization.

1 Introduction

User-centered design and usability evaluation go hand-in-hand. It is generally accepted amongst members of the HCI community that you cannot guarantee a successful user experience without testing it in some way [15], the earlier in the process, the better [34]. Indeed, it has even been argued, perhaps unfairly, that user-centered design is often little more than trial and error, guided by checks with users in evaluations [14]. Iterative design, prototyping and usability evaluation certainly ranked very high amongst all methods cited in two surveys of HCI professionals [20, 48]. Early, rapid and low-fidelity prototyping approaches (e.g., paper or look-and-feel mock-ups) allow ideas to be evaluated for usability with real users and then refined and tested again before design decisions are finalized and high-fidelity software prototyping affords even more thorough usability evaluation during the design process.

Evaluation performed *during* the design process is known as *formative evaluation* and can be contrasted with *summative evaluation* that can be used to assess the final merits of a system at the *end* of the design process [44]. Formative evaluation is useful for improving a design and summative evaluation for supporting claims to its efficacy and developing requirements for a future release of the design product. However, regardless of when and why evaluation is required, there is some considerable debate as to what usability evaluation methods are most effective (e.g. [18, 21 and 49]).

This paper briefly discusses the big picture of some of the issues that can influence the choice of a usability evaluation method within the user-centered design process. It

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is presented as context for a series of position papers within a panel that reflects on one particular effort to systematize usability evaluation in a large corporation where a number of fairly common constraints such as lack of availability of user-centered design experts and tight product deadlines and budgets apply.

2 Challenges for Usability Evaluation in Design

Despite the obvious importance of evaluation in user-centered design (obvious at least to our own HCI community), it is not always the case that applications built to be placed in the hands of hapless end-users enjoy the benefits of any kind of objective evaluation; i.e., a method relying on more powerful evidence than the intuitions of inexperienced engineers [see, for example, 6]. And HCI researchers have expressed concern that the evaluations that do take place are inadequate (for example, they may involve the wrong user representatives [19]; or only quality control testers [41]). In this section I review three obstacles that may stand as explanations for this unfortunate phenomenon.

2.1 A Plethora of Methods to Choose From

One key obstacle to understanding what usability evaluation methods one should adopt is the abundant diversity of methods and tools starting with “quick-and-dirty” methods such as expert reviews or guidelines walkthroughs [18] and simple tools such as surveys [e.g. 42] all the way through to extended in situ evaluation methods incorporating multiple data sources such as logging and interview-based data collection methods [e.g. 33] or sophisticated tools such as eye-tracking systems [e.g. 11]. Each method has its strengths and drawbacks and is appropriate in different circumstances, for example discount usability methods [36] are appropriate when resources are constrained, even if they are not as sensitive at picking up problems as a full-scale evaluation. If there were a one-size-fits-all solution available for standardized usability evaluation, it would surely be easier to train designers and developers to apply it in all projects that are likely to impact end users. But instead diversity opens the doorway to confusion and suboptimal choice.

2.2 A Diversity of Influential Design Circumstances

At the time of writing in 2009, based on my own experiences interacting with representatives of a variety of commercial and research application development organizations, it is still not uncommon for a design effort to take place without a serious usability evaluation. We are all familiar with the baffling results of such endeavors, which we encounter regularly in our interactions with hardware, software and web-based user interfaces.

Many circumstances can exert influence over whether usability evaluation takes place at all and over what type of evaluation with what metrics is most appropriate. Consider the following variables (which are both contextual and inherent to the design) as examples:

- Application domain
- Standards and performance criteria that pertain to the application domain

- Target users and their particular characteristics
- Novelty of the design and its interaction elements
- User-centered design expertise within the design team
- Budget
- Time available
- Organizational culture around the design team and perceptions of the importance of usability

Let me briefly illustrate the kinds of impact these factors can have. In my own past work exploring novel solutions in the application domain of personal information management (PIM) [8, 9 and 10], it quickly became apparent that experimental evaluations made no sense, since the proof of the PIM pudding so-to-speak can only be in the extended use of a solution with one's own real personal information, leading to a need for in situ evaluation of real use over weeks rather than the hours that Nielsen [38] suggests can usefully be applied to web-site evaluation. As another example, Grudin [19] reported extensively on various organizational related constraints that can lead to suboptimal design results and Bak et al. [6] more recently also highlight organizational obstacles as significant, both in the literature and in their own survey, together with developer mindset (a culture of greater focus on functionality and efficient code and lack of user-centered design expertise).

Perhaps the key factor impacting usability evaluation is the overall culture of the host organization for the design effort, (or even the culture within which that organization exists) which can in turn influence other factors that I listed above. Specifically, if few members of the organization are aware of user-centered design as a discipline and the value of a good user experience and fewer still have the relevant skills to apply the appropriate methods, then budget and time will not be allocated to a serious effort to evaluate the user experience and people with the required expertise will of course not be available to engage in that effort. In many countries today usability experts (or engineers who also have user-centered design skills) are indeed still an extremely rare species and, even if a corporation wishes to hire them, they may find that they simply cannot find them. In such circumstances, how might a large corporation make the best of limited usability expertise? This is an issue to which I will return in a subsequent section.

2.3 Metrics

Usability is defined in the ISO 9241-11:1998 standard 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." Taking this standard as widely agreed upon, effectiveness, efficiency and satisfaction thus have to be measured somehow in order to know how usable a prototype or product is. Unfortunately metrics also present something of a challenge to evaluators since, as Sauro & Kindlund [43] point out without overlooking the obvious irony, "Usability Metrics Need to be Easier to Use." Bak et al. [6] surveyed 2795 papers in the HCI literature, amongst which they found 28 with a focus on usability in organizations. Out of these, 11 mentioned poor understanding of usability as an obstacle (behind resource demands, 17/28; test participant issues such as identification and access to users, 14/28; and organizational obstacles including anti-usability culture, 14/28). In particular, according to Bak et al., usability is often confused with functionality, which, at least to this author's mind, may explain why so many applications have so many unused, often hard to discover, and near useless features.

In fact there are five basic (although not cleanly independent) usability metrics that have been applied repeatedly and seem to be accepted as fairly standard within the HCI community [e.g. 32, 34 and 43]. These are:

- Time taken to learn to execute tasks
- Time taken to execute tasks
- Task completion rate (proportion of tasks in an evaluation that can be completed to some standard of correctness)
- Number of errors (deviations from viable task completion paths or production of a result or state that must be undone)
- User satisfaction (a composite of a variable host of subjective assessments)

Other less common metrics such as objectively measurable stress [e.g. 45] and analytically derived cognitive complexity [27] that can be correlated with at least one of these four have also been discussed in the literature. However, the five basic metrics can be all measured directly without special equipment (although perhaps not always as accurately as with special equipment) and cover the most significant possible consequences of bad design.

The question then is, should all of these dimensions be measured or do some matter more than others in different design circumstances? In fact, design circumstances can heavily weight the importance of one metric over another and may even require trade-offs to be made between metrics. For example, a UI optimized for novice users with lots of easy to find and learn menus and buttons will tend to be slower and less efficient for an expert who will usually look for keyboard shortcuts that are faster to execute. So the evaluator must understand the importance of the metric to the design circumstances at hand and the extent to which any given tool or method is likely to provide reliable values for the metrics that matter.

Different usability evaluation methods vary in the extent to which they are able to provide these metrics. For example, a cognitive walkthrough [40] will not allow the evaluator to measure task times very accurately, although it may be better at measuring the extent to which a system is likely to be error-prone. A laboratory experiment may allow an evaluator to measure time, task completion and errors quite accurately, but render no reliable measurement of user satisfaction. A user survey may measure satisfaction quite well, but provide only subjective (and thus unreliable) appraisals of time, task completion and error proneness. Of course, it can make sense to combine multiple methods in one evaluation such as an experiment and a survey, usually at a reduced cost for each method, since study participants need only be recruited, scheduled and paid once for a single session to perform more than one exercise. Whatever the case may be, it requires some expertise to know what aspects of the design situation to pay attention to in deciding what evaluation metrics are best.

3 Systematizing Usability Evaluation

Given the above challenges for usability evaluation in the design process, it is hardly surprising that some professionals have sought to develop systematic methods in an attempt to help those with less expertise assess usability without the added time and expense of bringing in real users or an expert who may be hard to find. Three approaches to systematization are:

- Guidelines
- Procedures
- Automation

Usability guidelines have been common for quite some time. For example, Jakob Nielsen describes participating in a US Airforce exercise to compile "existing usability knowledge into a single, well-organized set of guidelines for its user interface designers" between 1984 and 1986 [37]. Many corporate, governmental and quite a few international user interface design guidelines have been compiled and updated since then [e.g. 5, 24, and 28]. They seek to describe what the designer must aim to accomplish or constraints she or he must work within. However conforming to guidelines can be a tricky business for the unskilled, especially when they are not well articulated as in the ISO guideline for "Suitability for learning" which is articulated thus, "A dialogue is suitable for learning when it supports and guides the user in learning to use the system."

Procedures is a term I want to use here to refer to well-defined methods for usability evaluation and count as a subset of the methods described in section 2.1 of this paper. The Cognitive Walkthrough [40] is one such procedure that has been evaluated [31] to show that it can be followed by a knowledgeable person and, depending on the extent of that person's skill, produce consistent predictions without requiring a complex modeling effort or a real user evaluation. Another similar approach is the Heuristic Evaluation method [39], which, in evaluation, has been shown to be better performed by usability experts and best of all by application domain specialist usability experts [e.g. 34]. These general-purpose methods have also been accepted for a long time and have stood the test of time, still being in use even over 15 years after their invention [22]. Earthy at al. [17] provides a review of the ISO 13407 human-centred design processes which represents an attempt to set standards for interactive systems design in general. Other evaluation procedures have been developed more recently for specific platforms (e.g. the mobile phone [30]) and specific application domains (e.g. e-learning [50]).

Automation may be the Holy Grail of usability evaluation since the possible cost savings in design endeavors are immense. Card, Moran & Newell developed the foundational example of an evaluative human information processing model and the GOMS (Goals, Operators, Methods and Selection rules) approach to computational modeling of human interaction with computers in the early 80's [13]. Since then, many attempts have been made to achieve full automation [25]. Quite a number of early efforts to develop approaches only focused on specifying the rules that would need to be learned by a user to operate a system and were never automated and took far too long to apply successfully [7]. More successful has been the work based on sustained development of working software models of a human information processor such as ACT [1] and its descendents (ACT* [2], ACT-R [3 and 4] and ACT-R/PM, [12], which is still under development at Carnegie Mellon University (CMU). Another, albeit less well-known, example of such a system is the SOAR cognitive architecture [29] developed in the UK.

Building upon the ACT-R computational cognitive architecture Bonnie John at CMU and her colleagues and students have developed a GOMS-based system called CogTool [26] that has perhaps come closest to achieving minimal effort from the system developer. CogTool uses performance measurements taken from real user interactions and is able to generalize them to specifications of user interfaces that contain the same basic features (e.g. buttons, menus and other GUI elements). The user interface specification is provided to CogTool in the form of a storyboard (based on sketches or screenshots) that preserves the dimensions of the target GUI upon which the evaluator demonstrates to CogTool the actions required to execute tasks. Using its models of user thinking times and actions (plus expected system response times), CogTool is able to output a metric of task completion time predictions for a skilled user and also completion times and deviating actions together with the time they will take for novices. CogTool uses an augmentation of ACT called SNIF-ACT [17] which assumes novice users read text labels and click on items that are semantically close to their goal, sometimes this will lead to mistakes since interfaces often contain ambiguous or misleading elements [46 and 47].

4 Seeking Systematization in the Enterprise

The HCI International 2009 panel, *"Systematization, Modeling and Quantitative Evaluation of Human Interface"* with which this paper is associated includes a number of positions from collaborators who have participated in an effort to systematize usability evaluation in a large corporation, NEC, based in Japan, that frequently develops software and hardware products for both consumers and for business use. The discussion in this paper has sought to provide some context for the approach adopted in the work reported, by addressing some of the key considerations that relate to its rationale.

The chosen approach reflects a desire to simplify the choice of usability evaluation method in NEC where usability expertise is not as pervasive as would be ideal and where tight deadlines and budgets always apply. A small team of usability specialists in the research division of NEC began a collaboration effort with researchers at the Palo Alto Research Center and at Carnegie Mellon University to validate the use of CogTool (introduced above) in assessing the usability of products under development. CogTool was chosen as an ideal method because of its being easy to apply to a graphical UI specification (possibly early in the design process) without much expertise. This approach sidesteps the problems experienced by the corporation of lack of expertise and limited time and budget for usability. By providing one general-purpose systematic approach, it also seeks to get around possible bewilderment by non-experts working at the corporation at the number of methods available and the reliance of many of the more suitable, under the circumstances, economical and fast discount usability methods (such as Heuristic Evaluation) on experts to apply them well.

Because of their importance to the corporation as a product category and the discrete, and thus easy to model, nature of the tasks users perform on them, mobile phones were chosen as having an ideal user interface upon which to first test the CogTool approach.

However, CogTool at the time of writing mainly generates predictions of the occurrence of user behaviors such as looking, thinking and gesturing and the time they each take during task execution (which may include trial-and-error exploration for novice users). So it was necessary to determine whether these predictions correlate with the kind of usability that really matters to a product vendor developing applications where user performance demands (i.e. time to execute tasks and error rates) are not stringent; the subjective experiences of both experts and novices. Experts, of course, will form this opinion over extended periods of use, but novices can only form this opinion based on hearsay from existing users (probably experts) or their own initial exploration of the product, perhaps in a store (also known as "shelf usability") or when given the opportunity to try the product for the first time by a friend or colleague.

A literature search was undertaken to find the best possible method for assessing user subjective impressions of usability. Out of many possible candidates, the Mobile Phone Usability Questionnaire developed by Ryu [42] was chosen because it built upon and systematically refined questions from a number of previously well-accepted subjective usability assessment questionnaires.

At the time of writing, an intensive effort is underway to obtain naïve and expert user performance data on a set of tasks across three types of mobile phone interface (between subject measures) and to correlate that data with user subjective impressions of usability obtained using the MPUQ both before and after using the mobile phones.

The anticipated outcomes of the research will be:

- A comparison of three mobile phone models in terms of time taken by expert and naïve users to complete a set of tasks on each of the three phones.
- CogTool predictions for both experts and naïve users on each of the phone interfaces and an assessment of the accuracy of those predictions.
- A comparison between the real user data and the CogTool predictions and user subjective impressions of usability.

If the team is able to demonstrate that predictions of CogTool do indeed correlate with user subjective impressions, then we have evidence that CogTool may be used by commercial mobile phone developers to improve the usability of their mobile phones by using its predictions as a means to identify usability problems and areas for improvement in new phone interface design efforts. Whilst this might not be the ideal method for formative usability evaluation in the product development lifecycle, it will be a practical solution that can be used by non-experts under non-ideal circumstances and should reduce instances of at least some types of usability problem going undetected before product release.

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