Technology Enhanced Interaction Framework:

Issues in evaluating a new software design framework and method

Kewalin Angkananon, Mike Wald, Lester Gilbert

***Abstract*— A Technology Enhanced Interaction Framework has been developed to support designers and developers designing and developing technology enhanced interactions for complex scenarios involving disabled people. A literature review showed that while there have been many studies concerned with methods for evaluating software designs few studies addressed ways to evaluate software design methods. Issues of motivation, time, and understanding when validating and evaluating the Technology Enhanced Interaction framework were identified through a literature review and questionnaires and interviews with experts. The advantages and disadvantages of a range of experimental design approaches to sourcing scenarios, gathering requirements and designing solutions were considered. Future work will consist of the implementation of a motivating user evaluation approach involving both self-evaluations by designers and expert evaluations that learns the lessons from others' experiences of software method evaluations.**

Keywords— ***interaction framework, software design, evaluation***

I. Introduction

This paper focuses on the issues involved with a user evaluation of the Technology Enhanced Interaction Framework (TEIF) adapted from and extending the work of Dix [1] and Gaines [2] to support developers and designers designing and developing technology enhanced interactions for complex scenarios involving disabled people. Section II explains the Technology Enhanced Interaction Framework and Method. Section III discusses evaluating software design methods. Section IV discusses issues in evaluating TEIF. Section V summarises conclusions and future work.

II. Technology Enhanced Interaction Framework and Method

The Technology Enhanced Interaction Framework supports developers and designers designing and developing technology enhanced interactions involving people, technology and objects and has seven main components as shown in Table 1 and an architecture shown in Figure 1. The TEIF method which has been described elsewhere [3-4] involves using the Framework to help identify interactions that cause issues for disabled people and using related technology suggestions to design technology enhanced interactions to overcome these issues.

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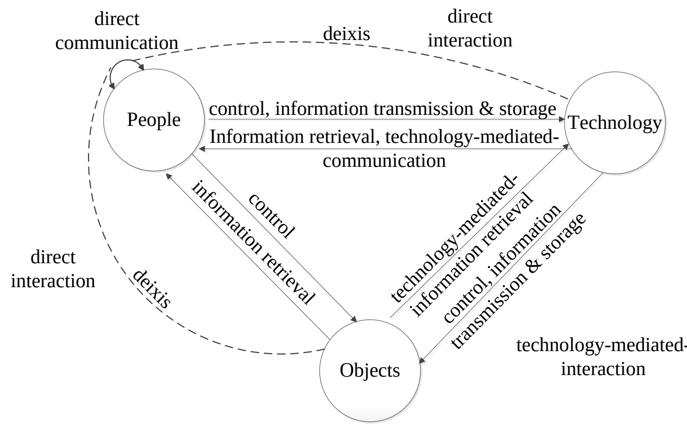

Figure 1. The Technology Enhanced Interaction Framework Achitechture

III. Research Methodology Issues

Triangulation is a technique used to ensure the validity and credibility of the results [5-7]and methodological triangulation is used based on theory of existing frameworks, expert validation and review, and user evaluation. Validation is an important process particularly when an instrument is being developed to measure the construct in the context of the concepts being studied [8]. Without validation, untested data may need revision in a future study [9].

The validation of the Technology Enhanced Interaction Framework was considered by two groups: designer/developer experts and accessibility experts. The designer/developer experts focused on the main and sub-components while accessibility experts focused on checking the accessibility aspects. The results of this validation have been reported elsewhere [10]. After the expert review and validation user evaluation involving real users (designers) will be used to evaluate the Technology Enhanced Interaction Framework and Method. Ryan and Deci [11] stated that there are two types of motivation: intrinsic motivation which refers to motivation that is animated by personal enjoyment, interest, or pleasure and is usually contrasted with extrinsic motivation, which is manipulated by reinforcement contingencies. Normally, extrinsic motivations are rewards (e.g. money or award) for showing the desired behaviour, and the threat of punishment when misbehaving. In order to engage the participants to become interested and engaged in a task which involves spending a lot of time thinking about and understanding a new idea both intrinsic and extrinsic motivation and Interaction Design components need to be considered.

Table 1 Main Component of Technology Enhanced Interaction Framework

Main Component	Main Component of Technology Enhanced Interaction Framework	
	Sub-component	***Example***
People	Role	A person has a role when communicating with others (e.g. presenter, audience, peer). Roles normally come in pairs such as speaker and audience (e.g. teacher and student or owner and visitor) and peer to peer (e.g. student and student or visitor and visitor).
	Ability/ Disability	People have abilities and disabilities which can affect their use of technology or understanding of language and which can lead to communication breakdown (e.g. physical, sensory, language, culture, communication, Information Technology (IT)).
Objects	Dimension	Objects have 2 dimensions (2D) or 3 dimensions (3D), and a 3D object may have a 2D representation.
	Property	Objects have colour, shape and size.
	Content	Objects have content which is human readable (text, pictures, audio, video) and machine readable (QR code, AR tag, barcode, RFID tag, NFC).
Technology	Electronic	Electronic technology has stored information, is online (e.g. internet, phone network) or offline (e.g. not connected to the internet or phone network), and is mobile (e.g. smartphone) or non-mobile (e.g. desktop computer).
	Non-electronic	Non-electronic technology is used to store information in objects (e.g. writing with a pen on paper) and is mobile (e.g. pen) or non-mobile (e.g. full-size desktop typewriter).
	Usability and Accessibility	People interact with technology through its user interface (e.g. touch screen, keyboard) that needs to be usable and accessible.
	Application or Service	Electronic technology is an application (e.g. dictionary) or a service (e.g. weather forecast).
	Cost	Technology has cost (e.g. of hardware, software, maintenance).
Interactions and Communication	People-People (P-P)	People communicate verbally (speak, listen, ask, answer) and non-verbally (lip-read, smile, touch, sign, gesture, nod). When communicating, people may refer (speak or point) to particular objects or technology – this is known as deixis.
	People-Objects (P-O)	People interact with objects for two main purposes: controlling (e.g. touch, hold or move), and retrieving information (e.g. look, listen, read, in order to get information or construct personal understanding and knowledge).
	People-Technology (P-T)	People control technology (e.g. hold, move, use, type, scan, make image, press, swipe) and transmit and store information (e.g. send, save, store, search, retrieve).
	People-Technology -People (P-T-P)	People use technology to transmit information to assist communication with (e.g. send sms, mms, email, chat, instant message) other people.
	People-Technology -Objects (P-T-O)	People use technology (e.g. point, move, hold, scan QR codes, scan AR tag, use camera, use compass) to transmit, store, and retrieve information (send, save, store, search, retrieve) to, in, and from objects.
Time/Place	Place	Same and different time and place yield four categories: same time (ST) and same place (SP), different time (DT) and same place (SP), different time (DT) and different place (DP), same time (ST) but different place (DP).
	Time	
Context	Location	Location affects the use of technology (e.g. indoors, outdoors). For example GPS does not work well indoors.
	Weather Condition	Weather condition may affect the use of technology (e.g. rainy, cloudy, sunny, windy, hot, cold, dry, wet). For example, the mobile phone screen doesn't work well in sunshine.
	Signal Type and Quality	Signal type can affect the quality of electronic technology (e.g. broadband, GPS, 3G, 4G).
	Background Noise	Background noise can affect the communication particularly for hearing impaired people (e.g. background music, crowded situation).
	Lighting	Light can affect the interaction (e.g. Inadequate light, too bright).
Interaction Layer	Culture	Cultural layer includes countries, traditional, language and gesture (e.g. "hello" is a normal greeting used in the culture).
	Intentionality	Intention layer involves understanding, purpose and benefit (e.g. the intent is a greeting).
	Knowledge	Knowledge layer involves facts, concepts, procedures, and principles (e.g. how to spell the word "hello").
	Action	Action layer involves actions and behaviours (e.g. pressing the correct key and not hitting neighbouring keys).
	Expression	Expression layer describes how actions are carried out (e.g. whether action is correct, accurate, prompt).
	Physical	Physical layer is the lowest layer at which people interact with the physical world (e.g. the button is depressed and so sends the electronic code for the letter to the application).

An important issue that can arise when users evaluate a new idea or concept using a prototype system is that they evaluate the system rather than the idea. Using a low fidelity prototype (e.g. paper) rather than a high fidelity prototype (e.g. a functioning website) can sometimes help the user focus on the idea rather than the system. However some users may find it more difficult to evaluate the potential of an abstract concept or idea than a concrete product [12]. Possible ways in which the designers/developers might evaluate the Technology Enhanced Interaction Framework will be considered before finally deciding on the method to be used. The advantages and disadvantages of some approaches are summarized in Table 2 and problems and possible solutions are presented in Table 3.

A literature review showed that while there have been many studies concerned with methods for evaluating software designs few studies addressed ways to evaluate software design methods. Evaluating Software Engineering Methods and Tools Part 1: The Evaluation Context and Evaluation Methods. ACM SIGSOFT Software Engineering Notes, 21, 11-14 is one of a series of notes based on the DTI-backed DESMET project [13] which analysed nine types of evaluation for evaluating a Tool, a Method and a generic Method. These were experiments, case studies and surveys, qualitative screening, qualitative effects analysis, and benchmarking. The project concluded that for evaluating generic methods, 'Qualitative Effects Analysis (A subjective assessment of the quantitative effect based on expert opinion) is likely to be appropriate because any quantitative evaluation would be based on a specific instantiation of the generic method.' For a comparative evaluation of TEIF, another method is required but a review of the literature provided little clear information about what would be a commonly used and well understood method and indeed Barry and Lang [14] found that 25% of the organisations and engineers surveyed do not use any method while 76% of those that use a 'method' mainly use their proprietary 'in house' methods. It would therefore appear sensible to allow users to choose whatever method they prefer to use in the comparison with TEIF.

Mayo et al [15] reviewed systems development methodology selection frameworks and investigated the consistency between methods practitioners claim to use to select software development methodologies and the methods they actually use in one organisation over a period of two years and found that changes in the projects characteristics (e.g. an experienced expert resigns) could result in changes in methodology. Twenty five percent of judgements on methodology characteristics were found to be inconsistent with practitioners recommending methodologies over others they evaluated as superior. They compare developmental approaches (lens to view everything through) with methods, models (arrangement of activities) and techniques (details of implementation).

Hooper [16] developed Teasing Apart, Piecing Together (TAPT) as a software engineering design process for analysing and redesigning experiences and evaluated it with a comparative evaluation with a 'scenarios' method of its use by software engineers, an expert review of the outputs of that evaluation and case studies of its use by professionals. The expert review of artefacts addressed the possibility of bias in participants' self-assessments, while the case studies examined TAPT's use in a more realistic field environment than the controlled lab based comparative experiments. Evidence from the expert review suggested that participants should have been given an opportunity to familiarise themselves with new methods through a 'trial run'. The comparative evaluation suggested that TAPT might be best used with a complementary method such as 'Scenarios'. Experts preferred artefacts produced with Unstructured Discussion compared to TAPT or Scenarios perhaps due to the fact that the structure of the artefacts produced by those methods was removed to help ensure the expert couldn't identify the method. Possible improvements to TAPT based on the feedback included encouraging practitioners to indicate in designs where they have included key effects from analyses.

Case study participants found TAPT and Scenarios to be complementary methods. One participant used TAPT as an evaluative tool, and reported finding the process helpful for better understanding the product he evaluated. Others applied TAPT to facets of an experience or to a list of project requirements. Hooper drew the analogy with Computer Scientists using parts of Unified Modelling Language (UML) best suited to the task at hand rather than as a rigid process and in a similar way parts of TAPT most appropriate to the problem being tackled can be used in an agile way.

While TAPT focuses on user experiences (UX) of technology rather than the TEIF focus of the accessibility of interactions the following lessons learned regarding evaluation of methods appear relevant to TEIF evaluation methodology:

- Participants should be given an opportunity to familiarise themselves with new methods
- Methodological aspects in the structure of artefacts should not be removed before expert evaluation
- Key effects from analyses should be shown in designs
- Users can use parts of a method in an agile way
- The method may be useful alongside other methods rather than replacing other methods
- Aspects of the design method may also be valuable as an evaluation method

IV. Issues in Evaluating TEIF Method

A. *TEIF Requirements Gathering*

There are alternative sources concerning software engineering requirements processes (e.g. Volere [17], IEEE Recommended Practice for Software Requirements Specifications [18] but they do not provide sufficient details for how to gather or identify the requirements for making interactions accessible. The TEIF does not aim to replace other approaches to gathering and identifying requirements but support this process with regard to the requirements for making interactions accessible. Three ways to gather and identify requirements in an experimental situation are a simulated interview, automated interview and document inspection and the main advantages and disadvantages are shown in Table 2.

B. *User Evaluation Experimental Design*

Three approaches to the user evaluation are provided in Table 3. Building a prototype can illustrate the capabilities of the system to users and designers and help evaluate whether the design can be developed into a solution; however building a working prototype can be expensive. Issues of time, motivation and understanding and their respective problems and possible solutions are described in Table 4.

C. *Source of Scenarios*

Scenarios for the user evaluation experiment can be artificially constructed or taken from the real world and the advantages and disadvantages of these two approaches are shown in Table 5. Slightly modifying real world scenarios can combine the advantages of both approaches.

Table 2 Requirements Gathering Approaches

Requirements Gathering Method	**Advantages**	**Disadvantages**
Simulated Interview (participants interview researcher or actor role playing 'client')	• High face validity as with a real interview the interviewer can ask the client to clarify any unclear information [19]. • Allows participation by people who have difficulty with reading or writing [19].	• The predisposition, experience, understanding, and bias of the interviewer influence the information obtained [20]. • The need for the use of actors to remove bias of researcher acting as interviewee • Reliability issues of how to consistently answer questions that are 'off script' • Can't stop for a break whenever they want • Need to arrange a suitable time and place
Automated simulated interview	• Selecting from list of questions which have built in answers make the interview process more reliable. The use of context-free questions by the interviewer helps avoid prejudicing the response [20].	• Low face validity and need to put into questions many 'distractors' as otherwise requirement questions are too obvious
Document inspection	• High reliability as all effective requirements are mentioned in the document. • The use of context-free questions to consider helps avoid prejudicing the response [20].	• Need to add many 'distractors' into document as otherwise requirement information is too obvious

Table 3 User Evaluation Approaches

Approaches	**Main Advantages**	**Main Disadvantages**
1) User self-evaluation after reading TEIF worked example	• Less time for participants than 2 and 3	• No opportunity to actually use the framework for design. Self-evaluation not objective.
2) Self and expert evaluation of solution built from requirements and design following TEIF method	• Designers may find it more enjoyable to design and develop and test and evaluate a real solution with disabled people than just reading and answering questions as in 1 or designing in 3 • Developing a working technology solution and evaluating it with disabled users provides greater face validity to the evaluation	• Most time for participants as will spend much time to design and build the prototype solution
3) Self and expert comparative evaluation of requirements and design from using TEIF and another method	• Designers may find it more enjoyable and motivating and engaging than 1 by using Framework to design their own solution rather than just reading and answering questions as in 1 • Provides comparison with other method(s).	• Participants spend more time than 1

Table 4 The Issues and Possible Solution of User Evaluation Approaches

Issue Type	**Actual Problem**	**Possible Solution**
Motivation	• If it takes a long time to finish the task it's difficult to find the participants	• Reward (i.e. prize, put their name on published paper)
	• Individual designers may get bored if just reading and answer the questions	• Get them to design because the nature of designers like designing more than reading • Inviting a group of people who have the same interest in designing and get them to interact so becomes a more interesting task • Help them to see how their work will be of value to others
Time	• Individuals designing using the new framework take too much time which affect ethics approval and obtaining participants	• Working in a team might be quicker • splitting the 'experiment' into separate parts (i.e. 1. identifying requirements and 2. designing so each take less than 1 hr)
Understanding	• Framework is difficult to understand	• Redesign the task so it helps understanding in as short a time as possible • Select participants with a good level of understanding of the task

Table 5 Source of Scenarios for User Evaluation

Source of Scenarios	Advantages	Disadvantages
Artificially constructed scenarios	High reliability as can provide appropriate scenario for method	Low face validity for generalisation of method
Scenarios taken from real world	High face validity of generalisation of method	Low reliability as may not provide appropriate scenario for method

V. Conclusion and Future Work

Issues of motivation, time and understanding were identified through a literature review and validation questionnaires and interviews. The advantages and disadvantages of a range of experimental design approaches to sourcing scenarios, gathering requirements and designing solutions were considered. Future work will consist of the implementation of a motivating user evaluation approach involving both self-evaluations by designers and expert evaluations that learns the lessons from others' experiences of software method evaluations.

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