The Development of a Usability Methodology Incorporating Eye Tracking for Developing Countries

Marco Pretorius
Nelson Mandela Metropolitan University
P O Box 77000
Port Elizabeth, 6031
Tel No: +27 41 504 2247
Fax No: +27 41 504 2831
Marco.Pretorius@gmail.com

André Calitz
Nelson Mandela Metropolitan University
PO Box 77000
Port Elizabeth, 6031
Tel No: +27 41 504 2639
Fax No: +27 41 504 2831
André.Calitz@nmmu.ac.za

Keywords: Usability methodologies, eye tracking, user interfaces.

The Development of a Usability Methodology Incorporating Eye Tracking for Developing Countries

ABSTRACT

Companies are increasingly making use of usability techniques to evaluate computer software and e-commerce applications. Managers are becoming aware of the different interaction techniques with computer applications and the individual needs of users with different education and cultural backgrounds. Eye tracking is increasingly being utilised as a supplementary method in usability evaluations and the usability testing of software applications. Eye movement data and eye fixations can supplement the data obtained through usability testing by providing more specific information on the user's visual attention. In the South African context, eye tracking is a relatively new field. Universities are investing in eye tracking technologies and businesses are increasingly utilising the expertise and services. There is an increasing need for usability methods combined with eye tracking to be utilised by practitioners and researchers in Southern Africa.

In developing countries, the computer and internet skills of users vary considerably and influence the user's ability to use interactive computer applications. In addition, cultural differences and language differences further influence a user's computer abilities. Usability research methodologies generally do not cater for users with different educational and cultural backgrounds. This study developed a usability methodology incorporating eye tracking that was suitable for the proposed research. The research followed a combination of case-study and action research. Three case studies were conducted, evaluating the usability of e-commerce applications by people from different cultural groups, including expert and non-expert participants. After each study the usability methodology was evaluated, updated and improved.

The contribution of this paper is to present a usability methodology for usability and eye tracking studies in the Southern African context taking the user's educational and cultural background, for example home language and computer expertise, into consideration. The study used participants from different cultural backgrounds and fourteen different language groups. The findings indicate that researchers must take the participants' cultural background into consideration and provide additional assistance during usability evaluations. The recommendations have significant implications for managers, information technologists, educators, website designers and usability evaluators.

Keywords: Usability methodologies, eye tracking, user interfaces.

1. INTRODUCTION

Businesses in Southern Africa are increasingly becoming reliant on computer software applications and are further developing e-commerce applications to remain competitive. The users of the e-commerce applications have different educational backgrounds and computer and internet experience. The users of the applications interact differently with the software applications due to their personal background and previous computer experience and knowledge. Managers in South Africa are increasingly realising the importance of usability evaluations of software and internet applications and marketing material (Savage, 2008).

The trend of using eye tracking as a supplementary method in usability testing is pursued internationally. Research has shown that incorporating eye tracking in usability research can provide positive benefits compared with traditional usability testing (Tobii Technology, 2009). Eye tracking is a relatively new field in Southern Africa, with the first eye tracking research in South Africa starting in 2004 at the Nelson Mandela Metropolitan University in Port Elizabeth. The use of eye trackers for usability research in South African universities is increasing. Industry is realising the potential and benefits of eye tracking in usability research, with companies purchasing their own eye trackers as well as consulting usability and eye tracking experts. A need has arisen for a suitable usability methodology that can be combined with eye tracking to be used by usability practitioners and researchers in Southern Africa. The goal of this paper is to provide a methodology for usability research incorporating eye tracking to be utilised in a South African environment.

In addition, Southern Africa has users with different cultural backgrounds (South Africa itself having 11 official languages), with a large portion of the population not being computer literate. In developing countries such as South Africa, the computer and internet skills of users vary significantly, and this influences the user’s ability to use interactive computer systems (Jason, 2008). Software systems and websites that have users with a typical South African profile will have several non-expert users. It is therefore important to consider the implications of expert and non-expert (beginners, novices, intermediates) users for usability testing and to include the recruitment of such users in a usability methodology.

A usability methodology to be used in the Southern African context must take the different educational and cultural backgrounds of the users into consideration. The preparation for the usability study; how to conduct the usability and eye tracking process during the usability test; and the type of post-test questionnaires to be used must further be adopted for the different user backgrounds.

Three usability studies were conducted in this study in order to develop and evaluate the proposed usability methodology, which included formal laboratory testing, eye tracking and post-test questionnaires. The first study investigated the usability of an assignment submission: *Learning management system*; the second study focused on the usability of a *university information portal*; while the third study examined the usability of an online *university library system*. The proposed usability methodology is a result of an initial methodology being compiled and improved with each study after lessons learnt have been incorporated. The contribution of this paper is to present a proposed methodology for usability and eye tracking studies in the South African context, taking into account the computer experience and the cultural background, such as the home language of the participant.

The paper is organised as follows: section 2 describes the problem being investigated and section 3 the research objectives and methodology. Section 4 provides the theoretical background on usability and eye tracking, as well as the difference between expert and non-expert users. Section 5 explains usability and eye tracking methodologies and techniques from literature. Section 5 also discusses the usability and eye tracking methodologies used in three studies. Section 6 proposes a usability methodology for usability and eye tracking studies in the South African context. Section 7 concludes and contextualises the findings and provides suggestions for future research.

2. THE PROBLEM INVESTIGATED IN THIS RESEARCH STUDY

The problem researched in this study is based on the usability research conducted internationally. International usability studies generally utilise users that have a higher standard of education and extensive computer experience. In South Africa, the general population has a diverse educational background and limited computer experience. Usability study methodologies must take novice (referred to as non-experts in this study) as well as expert users into consideration (Jason, 2008). This study investigates usability methodologies that incorporate eye tracking and evaluates and combines a number of usability methodologies into a single usability methodology. The proposed methodology is evaluated using three case studies, and an improved usability methodology is proposed to be utilised in a Southern African context. The home language of the participants in the three studies included: Afrikaans; English; French; Setswana; Shona; Yoruba; Sepedi; Tsivenda; Zulu; IsiNdebele; isiXhosa; SiSwati; Sesotho and Xitsonga.

3. RESEARCH OBJECTIVES AND RESEARCH METHODOLOGY

The research objectives of this study were to:

- identify a suitable usability methodology that could be utilised in a Southern African context;
- adopt the usability methodology with the aid of three case studies using action research; and
- propose an updated usability methodology for people with different computer skills and cultural backgrounds.

The research methodology follows a combination of a case-study approach and action research. Case studies emphasise the detailed analysis of a limited number of events or conditions and their relationships (Vosloo, 2004). Yin (2003) indicates that case-study research is not only a data collection approach or design feature, but that it does represent a comprehensive research strategy. Flyvbjerg (2006:229) emphasises that the researcher should be sensitive to the diversity of the cases, which is specifically important in this study, where people from different educational and cultural backgrounds were involved.

The action research spiral is an iterative process of "diagnosing, planning, taking action and evaluating" (Saunders *et al.*, 2009:147). Action research starts with a clear purpose. In this study the purpose was to adapt a usability methodology, taking users from different cultural groups into consideration. This is followed by diagnostics (fact finding), planning and decisions about the actions to be undertaken. The action research process focuses on change, taking action and evaluating (Saunders *et al.*, 2009:148). This process was followed by utilising the three case studies discussed in section 5.

4. LITERATURE REVIEW

Section 4.1 discusses usability evaluation, focusing on eye tracking as the main method utilised in this study. Section 4.2 reviews previous work done in evaluating computer user interfaces with expert and non-expert users.

4.1 Usability and eye tracking

Usability testing involves measuring the performance of users on tasks with regard to the ease of use, the task completion time and the user's perception of the experience of the software application *(*Preece *et al.*, 2002). Usability testing quantifies users' performance in terms of errors made and time to complete the performance, while user satisfaction questionnaires and interviews are used to elicit user opinions (Preece *et al.*, 2002). In 2007 this description was expanded to include the user experience by stating that usability included both the usability of the system, e.g. how effective, efficient, safe and learnable it is, and the users' experience when interacting with the system, e.g. how satisfying, enjoyable, or motivating the interaction is (Preece *et al.*, 2007). Formal usability testing is an empirical method that requires the design of a formal usability experiment that is carried out under controlled conditions. Usability testing can be conducted within a usability laboratory or by means of field observations. The usability evaluations for this research were conducted by means of a formal usability evaluation.

Usability testing is increasingly being combined with eye tracking evaluations. Eye tracking is based on the fact that a record of a person's eye movements while completing a task provides information about the nature, sequence and timing of the cognitive operations that took place while the person was performing a task (Rudmann *et al.*, 2003). Eye tracking can be defined as a technique used to record and measure eye movements (Tobii Technology, 2010). The human eye moves by alternating between saccades and fixations. A saccade is the quick movement of the eye in order to shift focus from one area to the next. A fixation is the time spent looking at the newly found area. An eye tracker follows the eye during its saccades and tracks the location of the fixation points. Software designers can gain useful information on human eye movements by tracking eye saccades and fixations.

In Human-Computer Interaction (HCI), eye tracking has been used to study the usability of web pages (Jacob & Karn, 2003; Savage, 2008), menu searching, information searching from web pages and search result evaluation (Aula *et al.*, 2005). Goldberg and Kotval (1999) propose several eye tracking measures when evaluating a computer user interface. The authors state that eye movements can drastically improve the inspection of users' strategies while using computer interfaces. Section 5 discusses different usability and eye tracking methodologies and techniques used by several authors.

4.2 Expert and non-expert users

Research has indicated that the skills and expertise of users utilising computer user interfaces differ significantly between computer experts and non-experts (Hurst *et al.*, 2007). In developing countries the difference between computer experts and non-experts is more noticeable, as many users lack basic computer skills. Research conducted by Jason (2008) has shown that the user's level of computer expertise influences the usability of computer applications. Pretorius *et al.* (2009) highlighted the influence of user skills and experience on the usability of websites and computer applications.

Different empirical definitions of expert and non-expert users exist, but two (strongly overlapping) criteria used for the differentiation between expert and non-expert users are the knowledge of and the time spent working with a particular user interface of a computer system (Prumper *et al.*, 1991). Given that expertise not only depends on the time spent working with or on a computer system, the term *non-expert* rather than *novice user* is used. Furthermore, the term non-expert is useful for grouping categories such as novice users and intermediate users; both are generally classified as non-expert users.

Miliszewska (2008) states that general ICT skills can be grouped into two categories:

- the use of software and hardware tools (Windows, word processing, spreadsheet applications, presentation software, database applications, web applications, mobile applications, mobile devices, hardware and software installation, principles of networks); and
- the responsible use of internet services (e-mail, web browsing, digital authoring, electronic databases, principles of digital communication).

Nielsen (1993) supports Prumper *et al*. (1991) and describes three main dimensions along which users' experience differs. These three dimensions are (Nielsen, 1993; Wu, 2000):

- experience with the system;
- experience with computers in general; and
- experience with the task domain.

The dimension most referred to when user expertise is discussed is the user's experience with the specific user interface (UI). Users are normally classified as either experts or non-experts, or somewhere in-between. Hence we refer to users with expertise between novice level and before expert as non-expert users. There is evidence to support the fact that non-expert and expert users behave differently (Hurst *et al*., 2007).

Research conducted by Savage (2008) on e-commerce website usability indicated that non-expert and expert users act differently when interacting with an e-commerce website. Savage (2008) evaluated users conducting purchases on the Kalahari.net website. The Kalahari.net home page had a large number of advertisements, as can be seen in Figure 1. Savage (2008) found that non-expert users did not explore the web page (Figure 1) like the expert users did (Figure 2). Savage found that expert internet users in her study disliked advertisements and ignored such content or were distracted altogether.

Figure 1: Heat map of Kalahari.net home page (non-expert user)

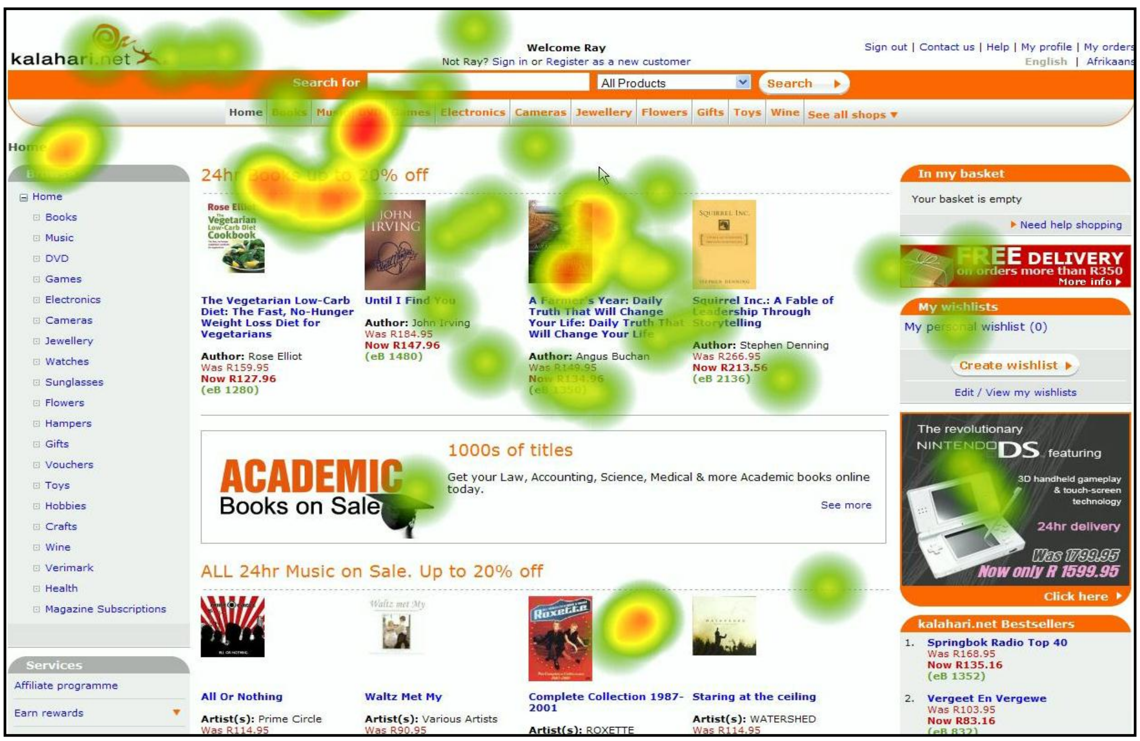

Figure 2: Heat map for Kalahari.net home page (expert user)

Eye tracking has been used to research the difference between experienced and less experienced users in information retrieval tasks (Dillon & Song, 1997), and different styles have been associated with experienced and less experienced users (Aula *et al*., 2005). In general expert users perform faster and more accurately and have more defined search paths, whereas non-experts waste time searching or looking at non-relevant information (Kasarskis *et al*., 2001; Law *et al*., 2004).

Pretorius and Van Biljon (2010) conducted a usability and eye tracking study on a university information portal. One task given to participants in this study was simply to find the web page of a certain college from the main page. Only six participants out of 15 found the required page on their 1st attempt. Five of these participants were non-expert users. The median time for non-expert participants to find the page was 37,125 s; while the time for expert participants was significantly longer at 62,857 s. Figure 3 and Figure 4 show the heat maps of non-expert and expert participants respectively. A heat map shows the fixations of a participant, where the "hot" colours indicate areas most fixated on by a participant. In Figure 3, the red rectangle illustrates the area where non-expert participants searched for this information. The heat map clearly shows that non-expert participants searched in the correct place. In Figure 4, once again the area to find the information is indicated by a red rectangle. The expert participants have almost no hotspots on the heat map, indicating that they did not expect to find the information in that specific location.

Van Biljon and Pretorius (2009) highlighted the effect of ICT user skills and experience on the usability of websites and computer applications. Their research study reported the combined results of three usability studies that included formal laboratory testing, eye tracking and post-test questionnaires. The usability and eye tracking data showed differences in terms of task time (considerably longer for non-experts) and scan paths (longer for non-expert participants, with more fixations scattered over the screen). This supports previous findings on the eye tracking patterns of experts (Law *et al*., 2004).

Pretorius and Van Biljon (2009) found several differences between expert and non-expert participants. Navigational difficulties are demonstrated in the following task from the study. Participants were required to find a library link on the university website. Usability data showed that all non-expert participants had difficulty in finding the library link: four participants gave up on finding the library link and needed directions to continue; while two participants first clicked on various other pages. Expert participants found the link without any difficulty.

Figure 3: Heat map of non-expert participants

Figure 4: Heat map of expert participants

Figure 5 demonstrates the eye movements of a non-expert user on the home page. Participants were searching for the library until the participant clicked on the correct link. The main goal in Figure 5 was to see what areas of the screen participants viewed the most, and where they searched for this information. The many fixations show how this non-expert participant struggled to find this information.

Non-experts had more difficulty in understanding the comprehension of terminology and error messages. They repeated their mistakes and received the same error messages repeatedly because they did not have the domain knowledge to understand the message. The results of the study indicated that ICT skill and experience influence the usability of systems to the point where a severe lack of ICT skills can make a system inaccessible and difficult to use. Working with ICT non-experts requires more structure in terms of doing tasks, more assistance and encouragement in reporting problems. It is therefore important to include both expert and non-expert participants in usability studies in the South African context. Section 5 explains the participant profile for the studies and how the participants were recruited.

Figure 5: Non-expert (novice) participant scan path – many fixations searching for the correct data

5. USABILITY AND EYE TRACKING METHODOLOGIES AND TECHNIQUES

This section presents an overview of guidelines for eye tracking and usability methodologies and techniques that are discussed in literature. Table 1 illustrates different eye tracking techniques by several authors used before the usability test, during the test and after the test, and the analysis of the data (Benel & Ottens, 1991; Xu, 2000; Cowen *et al.*, 2001; Gao, 2001; Goldberg *et al.*, 2002; Renshaw *et al.*, 2003).

Table 2 summarises usability evaluation guidelines by several authors (Rubin, 1994; Dumash & Redish, 1999; Faulkner, 2000; Barnum, 2002; Rosson & Carroll, 2002). These guidelines include the planning of the test, determining what to test, test material preparation, conducting the test, analysing the data and reporting the results.

The usability and eye tracking guidelines listed in Tables 1 and 2 were used to compile an initial methodology for usability and eye tracking studies. The usability methodology has been refined in recent years (Pretorius & van Biljon, 2009). Recent literature (Pernice & Nielsen, 2009) on eye tracking methodologies includes authors utilised in this study. The next subsection discusses several studies in which this methodology was used and improved. Section 6 presents the improved technique based on the methodologies and techniques given in Table 1 and Table 2. Furthermore, the proposed usability methodology is a result of lessons learnt and improvements made from the studies listed below.

Table 1: Summary of eye tracking procedures

	Xu (2000)	Gao (2001)	Goldberg *et al*. (2002)	Cowen *et al*. (2001)	Renshaw *et al*. (2003)	Benel and Ottens (1991)
Before the test	Welcome the participant.			Explain the task process to the participant.	Explain the task process to the participant.	Brief the participant (process and equipment).
				Show and explain the equipment to the participant.		
	Administer consent form.		The participant completes consent and disclosure forms.	The participant completes a consent form.		
	Pre-test questionnaire.	Pre-test questionnaire.	Demographic questionnaire.			
		Interface introduction.				
	The participant reads the notes.		The participant conducts three training tasks.			
The test	Calibration of the system's components.	System calibration.				
	Subject setup and calibration.	Subject calibration.	Eye tracker headband mounted. Subject calibration.	Eye- tracker headband mounted. Subject calibration.	Subject calibration.	Subject calibration.
	Data recording.	Data recording.		Record the data. Save the data files.		
			Conduct the test.		Conduct the experiment and record the data.	Conduct the experiment and record the data.
After the test	Post-test questionnaire.	Post-test questionnaire.	Post-task questionnaire.		Post-test questions.	Post-test questions.
	Participant signs payment form.					
	Thank the participant.		Experimental debriefing.			
Analysing data	Data analysis.	Data processing and image capture.	Data reduction.	Data analysis.	Data analysis.	Data analysis.

The selected usability methodology was used and updated in the following three case studies. This section discusses the action research conducted with the aid of three case studies, with users having different levels of computer expertise and from different cultural groups. The background and participant profile for each study are provided and is followed by an explanation of how the tests were conducted. Finally, the data collection is discussed, and how the usability methodology was updated.

Table 2: Summary of usability evaluation guidelines					
	Barnum (2002)	**Dumas and Redish (1999)**	**Rosson and Carroll (2002)**	**Rubin (1994)**	**Faulkner (2000)**
Test planning	Select the test team.				
	Define product issues and audience.	Define goals and concerns.			Identify the problem and formulate the hypothesis.
	Establish user profile. Recruit participants.	Select and recruit test participants.	Recruit test participants.	Select and acquire participants.	
	Select tasks to include in the test.	Create task scenarios.	Create task scenarios.		
	Determine how to categorise results.	Select and organise tasks to test.			
	Develop the test plan			Develop the test plan.	
Determine what to test	Set goals and measurements.	Define usability measurements.	Develop usability specifications.		
Test material preparation	Prepare the test materials.	Prepare the test materials, environment and team.	Develop the test materials.	Prepare the test materials.	
Conducting the test	Conduct walkthrough and pilot.	Conduct a pilot test.	Conduct a pilot test.		Design and execute the experiment.
	Greet participant and administer forms.	Care for the participants.			
	Brief the participant on the process.				
	Conduct the test.	Conduct the test.	Conduct the test.	Conduct the test.	
	Debrief the participants.		Debrief the participants.	Debrief the participants.	
Analysing data	Analyse the data.	Tabulate and analyse data.			Examine the data.
Reporting the results	Report the results.	Recommend changes and communicate results.	Report the test results.	Transform the data into findings and recommendations.	Communicate the results.

5.1 Study 1

Study 1 investigated the usability of an assignment submission of a *learning management system (LMS)*. Ten participants were used: five expert and five non-expert participants. The intended user group for the LMS is students who have to submit assignments online. A screening questionnaire was used to screen the participants for this evaluation. This questionnaire reflected the possible participant's LMS experience, computer experience, culture, age and gender. Regarding expert and non-expert users, results showed that individuals' ratings of their overall knowledge were better predictors than were estimations of frequency of use (Wu, 2000). The screening questionnaire asked participants to rate their experience level as an internet user. The following ratings were available: Never used the web; *Beginner*: have read pages on the web; *Novice*: have entered addresses and used bookmarks; *Competent*: can use a search engine to find information; and *Proficient*: know my way around and have done web transactions like e-banking. From the 23 questionnaires completed, 10 participants were selected, five who had rated themselves as proficient internet users and another five who had rated themselves as between a beginner and a competent level. The first group were referred to as expert participants and the latter group as non-expert participants.

The participants had all used some sections of the LMS; their computer experience ranged from less than one year; between one and two years; and two years or more. Experience of the system was distributed fairly equally between the groups. The participants included five male and five female students. The mother tongue (first language they had learned to speak) of the 10 participants was as follows (number of participants indicated in brackets): English (2); isiXhosa (2); Afrikaans (2); SiSwati (1); Sesotho (1); Xitsonga (1); and Yoruba (1).

5.2 Study 2

Study two investigated the usability of a *university information portal*. Ten respondents participated: four expert and six non-expert respondents. The intended user group for the information portal website was prospective and current students, as well as academic and administrative staff at the university. A screening questionnaire was used to select the participants for this evaluation. The questionnaire reflected the possible participant's internet experience, specific website experience, computer experience, culture, age and gender.

The participants were ranked as expert or non-expert participants, like in study 1. From the 35 questionnaires completed, 10 participants were selected: four who had rated themselves as expert users and another six who had rated themselves as non-experts. Eight participants were prospective and current students and two were staff members. Experience of the system was distributed fairly equally between the groups, with experience ranging from never; less than one year; between one and two years; and two years or more. The mother tongues of the 10 participants were as follows: Afrikaans (3); English (2); Sepedi (1); Tsivenda (1); Zulu (1); Setswana (1); and IsiNdebele (1).

5.3 Study 3

Study 3 was done on a *university library website*. Specific focus was given to a potential new home page design. The intended user group for the library website is prospective and current students as well as staff members. A screening questionnaire was used to select the participants for this evaluation. This questionnaire reflected the possible participant's internet experience, library website experience, computer experience, culture, age and gender. Ten users were selected for this usability study. The participants were ranked as expert or non-expert participants, like in studies 1 and 2, and they included a range of experience with the library website. The mother tongues of the 10 participants were as follows: Afrikaans (3); English (2); French (2); Setswana (1); Shona (1); and Yoruba (1).

5.4 Usability studies

The three studies were conducted in a similar fashion, with the differences as explained below. One participant was tested at a time. On arrival, the participant was briefed about the experiment, which was followed by an explanation of the equipment to be used. The details of the material to be recorded were explained and the participant was required to complete an informed consent form. This was followed by a 9-point eye tracking calibration. Participants were briefed about the systems and task list.

- Study 1 used a variation of the think aloud protocol, where participants were asked to comment if they were looking for something and could not find it; if they liked something particular about the website; and if they disliked something particular. The participants sat on their own to complete the tasks, with the facilitator sitting behind one-way glass. This was found to be a limitation, because some participants appeared uncomfortable sitting on their own, and when the facilitator spoke through the microphone, several participants turned around. This caused momentary loss of eye tracking data. Study 1 had the participants reading the tasks from a task list, and this also caused the participants to look away from the screen and to interpret the questions by themselves.

- Like in study 1, study 2 made use of the think-aloud protocol. This protocol had certain limitations. A few participants, possibly shy/introverts, did not always comment and had to be prompted for comments. The eye tracking data was also affected, as participants produced eye movements that they would not normally do. This study had the facilitator sitting with the participant, with the facilitator asking questions determined by the participant's website behaviour. This method was found to be more effective. Participants felt more comfortable with the facilitator by their side. Study 2 had the facilitator prompting the participant to complete a task; the participant did not have to read anything. This proved to be a more effective method, specifically for people with different home languages (other than English) and limited computer experience (non-experts). If participants did not understand a question, it could be explained to them in more detail.

- Study 3 made use of the retrospective think-aloud (RTA) protocol, where participants provided a description of their experience in doing the task after they had completed it (Tobii Technology, 2009). Like in study 2, this study had the facilitator sitting with the participant asking questions from the task list. The facilitator also asked questions determined by the participant's website behaviour. Think-aloud protocol was not used during this study. The participants were allowed to carry out a task till completion or up to a point where they needed assistance. After this, participants were asked questions about each task, for example what they expected; and what they had liked or disliked. The eye tracking analyses were done for the sections mentioned first, and not for the sections where participants explained their actions. This method proved to be more effective than the think-aloud protocol variation.

Following the tasks for studies 1 and 2, an interview was conducted to ask the participants what they had liked the most about the system and what they had not liked, as well as questions about issues that the administrator had picked up. Study 3 included this quick interview as part of the RTA. This was followed by a post-test questionnaire and a debriefing, where the participant was thanked and given the opportunity to observe the data.

5.5 Data collection

Data was collected and calculated as follows: live video recordings were captured, including the screen, participant's face and mouse/keyboard movements; notes were taken during the test and a full evaluation of the video was done at a later stage; audio in the form of the participant or the test administrator speaking was included with the video files; eye-tracking video recordings included a cursor that indicated the participant's eye movements; eye tracking data files were set up, and a post-test questionnaire was used to capture the participants' perception of the user interface and the system. Tasks were also monitored continuously. The usability metrics of these studies included: task completion rate; number/percentage of tasks completed with and without assistance; error rate recovery; task completion time; real-time events (mouse clicks, keyboard presses); and a post-test questionnaire. The eye tracking measures used in these studies included the number of fixations; number of fixations on each area of interest (AOI); time to the first fixation on an AOI, and scan path.

The studies used one or more of the following post-test questionnaires: Computer System Usability questionnaire (Lewis, 1995); System Usability Scale (SUS) questionnaire (Brooke, 1996); and open-ended questions relating to the participants' perception of the system.

Figure 6: The usability laboratory: observer room

Figure 7: The Tobii T60 eye tracker (usability laboratory - participant room)

The usability laboratory consisted of an observer room (Figure 6) and a participant room (Figure 7), separated by a one-way mirror. The participant room was equipped with a 17" TFT monitor with resolution of 1280x1024 and a Tobii 1750 eye tracker, allowing the eye movement of participants on the screen to be recorded. A nine-point eye tracking calibration was used at all times. The calibration process required a participant to look at several points/marks on the screen in order to set up the eye tracker and to ensure accuracy. During this calibration the eye tracker recorded the value that corresponded to each gaze position.

6. THE PROPOSED USABILITY METHODOLOGY

This section presents a proposed usability methodology based on the methodologies and techniques provided in Table 1 and Table 2. Furthermore, the proposed usability methodology is a result of lessons learnt and improvements made from the studies listed in section 5.

6.1 The evaluation methodology

Usability evaluation methodologies suggested by Barnum (2002), Dumas and Redish (1999), Rosson and Carroll (2002), Rubin (1994) and Faulkner (2000) were investigated for this research. Eye tracking techniques by Goldberg and Kotval (1999), Xu (2000), Gao (2001), Goldberg *et al*. (2002), Cowen *et al*. (2001), Renshaw *et al*. (2003) and Bennel and Ottens (1991) were combined with appropriate usability evaluation methods. Pretorius *et al*. (2005) suggested a methodology based on this research for network management tools. A methodology based on the methodology by Pretorius *et al*. (2005) was used in three usability and eye tracking studies where the usability methodology was improved after every test on the basis of lessons learnt in the tests. Table 3 gives the improved usability methodology, combining usability-evaluation techniques with eye tracking techniques. Table 3 lists the basic steps involved in planning and effectively implementing a formal usability test. Step 13, conduct the usability test, was where the majority of the improvements were made. The steps included briefing the participant, administering the forms, calibrating the eye tracker, recording data and debriefing the participant. Section 6.2 (Table 4) discusses this step in more detail.

Step 11 lists the recruitment of participants. It is important to select participants who are representative of the background and abilities of the intended users of the product. Once the user profile has been developed, a screening questionnaire can be used to ensure that prospective participants match the characteristics as determined. As was mentioned in section 4.2, it is important to consider both expert and non-expert participants when South Africans are the intended users. South Africa has 11 different official languages. Participants speaking several different languages were recruited in each test. Initial analyses showed that participants with English as first language performed better than participants with another language as their first language. Future work will investigate the role of home language in usability analysis in more detail.

Table 3: The proposed usability methodology	
Step	**Step description**
1	Establish the team.
2	Define the product issues and audience.
3	Formulate the research hypothesis.
4	Set goals and define usability measurements.
5	Define eye tracking metrics.
6	Establish the user profile.
7	Select the tasks to include in the test.
8	Determine how to categorise/analyse results.
9	Develop and write the test plan.
10	Prepare the test materials, environment and team.
11	Recruit the test participants (experts and non-experts).
12	Conduct a pilot test.
13	Conduct the usability test.
14	Tabulate and analyse the data.
15	Recommend changes.
16	Report the results.

Including eye tracking in the proposed methodology has certain limitations. There are many eye tracking devices available today, some more suitable for usability laboratory tests and other more suitable for outdoor tests. It is important to select one that will comply with the experiment's specific needs. The Tobii 1750 eye tracker was used during this study. The eye tracker device needs to be calibrated for each participant before a test. The selection of participants has to be done carefully, since not all participants can be calibrated and tracked successfully. Certain individuals' eyes cannot be tracked due to external reasons, such as glasses or contact lenses. The Tobii 1750 proved to be more reliable than previous eye trackers used, when participants with glasses had been participating. Other issues may also cause problems, including the pupil of the eye not reflecting enough light, or the iris being too light in colour to distinguish it from the pupil reflection. Future eye tracking studies will include studies on the Tobii T60 eye tracker (Figure 7), one of the latest available eye tracking technologies.

6.2 Procedure during the test

This process, step 13 of the proposed methodology, is presented in Table 4. It is based on only one person conducting and facilitating the test. All these studies were conducted with one person conducting and facilitating the test. Additional resources were not available. When a second or third person is available, they can log activities while the facilitator can focus only on facilitating. All the data is recorded, so having activities logged during a live test is not necessary. Participants should be assisted and encouraged to ask questions, especially participants from non-English-speaking countries, as was observed in the three studies conducted.

7. CONCLUSION AND FUTURE WORK

The goal of this study was to provide a proposed usability methodology (Table 4) for usability research with supplemental eye tracking in a South African context, where a large section of the population does not have the required computer and internet expertise and come from different cultural backgrounds. Expert and non-expert participants were recruited for the three studies discussed in this paper, including people with different cultural backgrounds and home languages. The results of these studies (Van Biljon & Pretorius, 2009; Pretorius & Van Biljon, 2009) (not included in this paper) showed a clear distinction between expert and non-expert users aligning with previous studies (Hurst *et al*., 2007). It is important to include participants with different cultural backgrounds and first languages, as English first-language participants tended to perform better than participants with other first languages.

Table 4: The proposed usability methodology for the Southern African context

Step	Step description
1	Welcome the test participant.
2	Brief the participant. • Introduce the observers. • Show and explain the equipment to the participant. • Explain the website/system being evaluated. • Explain the task process to the participant. • Remind the participant that the product is being tested and not the user. • Switch all cell phones off.
3	Administer forms and consent form.
4	Participant eye calibration.

5	Conduct the test.
	• Record eye tracking data (with face and sound).
	• Sit with the participant while doing tasks.
	  ○ Give the tasks to participants by informing them (do not let the participants read from a list).
	  ○ Prompt for answers/thoughts when struggling. **(An important step in developing countries).**
	• Log important participant activities.
	• Save the data files after the test.

6	Retrospective think aloud • Quick interview - what did you like or dislike. • Troublesome/highlighted areas – show eye tracking. • Keep the recording running for final comments.
7	Administer post-test questionnaire. • Open the website/system – option for participants to look back for information. • Use a standard usability questionnaire plus an open-ended questionnaire.
8	Debrief the participant.
9	Hand incentive to participant and thank the participant.

The focus of this paper was the development of a usability methodology and techniques that could be utilised to conduct similar studies in Southern Africa. A literature study was done on existing usability and eye tracking methodologies and techniques. A variation of a combined methodology by Pretorius *et al*. (2005) was used in these studies, with participants from fourteen different language groups. Study 1 used a variation of the think-aloud protocol, where participants were asked to comment if they were looking for something and could not find it; if they liked something in particular about the website; and if they disliked something in particular. The participant sat on his/her own, completing the tasks, with the facilitator sitting behind one-way glass.

Study 2 made use of the same variation of the think-aloud protocol. This study had the facilitator sitting with the participant, with the facilitator asking questions determined by the participant's website behaviour. The participants appeared much more relaxed with the facilitator by their side and more data was also collected, with the facilitator being able to ask questions more freely. Study 3 made use of the RTA protocol, where participants provided a description of their experience doing the task after completion. Using traditional think-aloud protocol in combination with eye tracking has proven to be less suitable, as participants then produce eye movements that they would not normally do if completing their task on their own in their normal environment (Kim *et al*., 2007). The RTA, combined with the facilitator sitting next to the participant, was found to be the most suitable in the South African context.

A proposed usability methodology for usability testing supplemented by eye tracking is provided (Tables 3 and 4): a result of the lessons learnt and improvements made from the studies discussed in this paper. Specific consideration was given to the procedure during the test (step 13 in Table 3; Table 4) and includes welcoming and briefing the participant, administering the forms, calibrating the eye tracker, recording data, RTA, administering post-test questionnaires and debriefing and thanking the participant. Future research will apply these findings on related and internet-based systems and further investigate guidelines for systems to accommodate both expert and non-expert users. The usability methodology will also be applied to other developing world countries and related websites and systems. Future work will further include the comparison of recent methodologies (Pernice & Nielsen, 2009) with the usability methodology presented in this paper.

The role of home language in usability evaluations was initially perceived to be an important research variable that the authors would have liked to have investigated in detail. The research has highlighted the importance of the variable, but the authors could not conclude any meaningful results on the influence of home language from the three case studies, however. Specific usability studies taking this important variable into consideration should be conducted in the future.

The role of expert versus non-expert participants indicated that expert participants performed noticeably better than the non-expert participants. Non-expert participants completed tasks more slowly and required more assistance. These results were validated by results from Jason (2008) and Savage (2008).

Managers in South Africa are increasingly realising the importance of the usability analysis of computer applications and the websites of a business, specifically when the applications are utilised by people from different educational, cultural and language backgrounds. Marketing material is increasingly being tested for layout, customer attention and brand awareness. Usability analysis can provide valuable feedback to managers and marketing professionals. New mobile usability technologies are becoming available in South Africa that customers can use in real-life situations in order to track eye movement and conduct eye tracking studies.

REFERENCES

Aula, A., Majaranta, P. & Räihä, K. 2005. Eye-Tracking Reveals the Personal Styles for Search Result Evaluation. INTERACT 2005, LNCS 3585 M. Costabile & F. Paternò**:** pp. 1058-1061.

Barnum, C. 2002. Usability Testing and Research., The Allyn and Bacon Series in Technical Communication.

Benel, D. & Ottens, D. 1991. Use of an Eye Tracking System in the Usability Laboratory. Proceedings of the Human Factors Society 35th Annual Meeting.

Brooke, J. 1996. SUS: a "quick and dirty" usability scale. London: Taylor and Francis.

Cowen, L., Ball, L. & Dekin, J. 2001. An Eye Movement Analysis of Webpage Usability. Proceedings of the annual HCI 2002. pp. 317-335.

Dillon, A. & Song, M. 1997. An empirical comparison of the usability for novice and expert searchers of a textual and a graphic interface to an art-resource database. *Journal of Digital Information* 1(1).

Dumash, J. & Redish, J. 1999. A Practical Guide to Usability Testing. Intellect Books.

Faulkner, X. 2000. Usability Engineering. Macmillan Press.

Flyvbjerg, B. 2006. Five Misunderstandings About Case-Study Research. *Qualitative Inquiry*, 12(2): 219-245.

Gao, T. 2001. Processing Numeric Table Data in Electronic Formats: Eye Movement Patterns and Searching Efficiency. Masters Paper. UNC School of Information and Library Science.

Goldberg, J. & Kotval, X. 1999. Computer Interface Evaluation Using Eye Movements: Methods and Constructs. *International Journal of Industrial Ergonomics*, 24: 631-645.

Goldberg, J., Stimson, M., Lewenstein, M., Scott, N. & Wichansky, A. 2002. Eye Tracking in Web Search Tasks: Design Implications. (*In* Proceedings of the symposium on ETRA 2002: Eye tracking research & applications symposium, pp. 51-58.)

Hurst, A., Hudson, S.E. & Mankoff, J. 2007. Dynamic detection of novice vs. skilled use without a task model. (*In* Proceedings of the SIGCHI Conference on Human Factors in Computing Systems., San Jose, CA, 2007.)

Jacob, R.J.K. & Karn, K.S. 2003. The Mind's Eye: Cognitive and Applied Aspects of Eye Movement Research Hyona, Radach & Deubel, Elsevier Science.

Jason, B. 2008. An Adaptive User Interface Model for Contact Centres. Department of Computer Science and Information Systems. Nelson Mandela Metropolitan University, Port Elizabeth. MSc Dissertation.

Kasarskis, P., Stehwien, J., Hickox, J. & Aretz, A. 2001. COMPARISON OF EXPERT AND NOVICE SCAN BEHAVIORS DURING VFR FLIGHT. 11th International Symposium on Aviation Psychology Columbus, OH: The Ohio State University.

Kim, B., Dong, Y., Kim, S. & Lee, K. 2007. Development of Integrated Analysis System and Tool of Perception, Recognition, and Behavior for Web Usability Test: With Emphasis on Eye Tracking, Mouse Tracking, and Retrospective Think Aloud. Usability and Internationalization. HCI and Culture, Second International Conference on Usability and Internationalization, UI-HCII 2007, Held as Part of HCI International 2007, Beijing, China, July 22-27, 2007, Proceedings, Part I 2007.

Law, B., Atkins, M.S., Kirkpatrick, A.E., Lomax, A.J. & Mackenzie, C.L. 2004. Eye Gaze Patterns Differentiate Novice and Experts in a Virtual Laparoscopic Surgery Training Environment. Association for Computing Machinery.

Lewis, J.R. 1995. IBM Computer Usability Satisfaction Questionnaires: Psychometric Evaluation and Instructions for Use. *International Journal of Human-Computer Interaction*. 7(1): 57-78.

Miliszewska, I. 2008. ICT Skills: An Essential Graduate Skill in Today's Global Economy? Proceedings of the Informing Science & IT Education Conference (InSite 2008).

Nielsen, J. 1993. Usability Engineering, Academic Press.

Pernice, K. & Nielsen, J. 2009. Eyetracking Methodology: How to Conduct and Evaluate Usability Studies Using Eyetracking. Nielsen Norman Group. [online]. Available at: <http://www.useit.com/eyetracking/methodology> Accessed: 10 August 2010.

Preece, J., Rogers, Y. & Sharp, H. 2002. Interaction Design: beyond human-computer interaction., John Wiley & Sons, Inc.

Preece, J., Rogers, Y. & Sharp, H. 2007. Interaction design - beyond human-computer interaction. New York: John Wiley & Sons, Inc.

Pretorius, M.C., Calitz, A.P. & Van Greunen, D. 2005. The Added Value of Eye Tracking in the Usability Evaluation of a Network Management Tool. (*In* Proceedings of the 2005 annual research conference of the South African Institute of Computer Scientists and Information Technologists on IT research in developing countries, White River, South Africa.)

Pretorius, M.C., Calitz, A.P. & Jason, B. 2009. Added value of usability and eye tracking techniques in design evaluations for expert and non-expert user interfaces. Third International Business Conference. 16-17 September 2009, Zanzibar Beach Resort, Zanzibar.

Pretorius, M.C. & Van Biljon, J. 2009. Website usability evaluation: Reliability of questionnaires in the South African context. 11th Annual Conference on World Wide Web Applications. 2009. Port Elizabeth, South Africa.

Pretorius, M.C. & Van Biljon, J. 2010. Beyond the haves and have-nots. E-Skills Summit 2010. Cape Town, South Africa. 26-28 July 2010.

Prumper, J., Frese, M., Zapf, D. & Brodbeck, F.C. 1991. Errors in computerized office work : Differences between novices and expert users. *SIGCHI Bulletin* 23(2).

Renshaw, J.A., Finlay, J.E., Tyfa, D. & Ward, R.D. 2003. Designing for Visual Influence: an Eye Tracking Study of the Usability of Graphical Management Information. INTERACT2003, Ninth IFIP TC13 International Conference on Human-Computer Interaction., Zurich, Switzerland, September 2003.

Rosson, M. & Carroll, J. 2002. Usability Engineering: Scenario-Based Development of Human-Computer Interaction., Morgan Kaufmann Publishers.

Rubin, J. 1994. Handbook of Usability Testing. John Wiley & Sons, Inc.

Rudmann, D.S., McConkie, G.W. & Zheng, X.S. 2003. Eye tracking in Cognitive State Detection for HCI. ICMI'03, November 5–7, Vancouver, British Columbia, Canada.

Saunders, M., Lewis, P. & Thornhill, A. 2009. Research methods for business students. 5th ed. Prentice Hall.

Savage, R. 2008. The Contribution of Eye tracking in E-Commerce Web Site Usability Evaluations. B.Sc Honours Treatise. Department of Computing Sciences, NMMU, Port Elizabeth.

Tobii Technology. 2009. Retrospective Think Aloud and Eye Tracking. [online] Available at: <http://www.scribd.com/doc/20155331/Tobii-RTA-Whitepaper> Accessed: 08 October 2009.

Tobii Technology. 2010. An introduction to eye tracking and Tobii Eye Trackers. [online] Available at: <http://www.scribd.com/full/25907389?access_key=key-124maqcut1ecaeyuic0j> Accessed: 03 July 2010.

Van Biljon, J. & Pretorius, M.C. 2009. Usability of learning management systems: Do Information and communication technology skills widen the gap? *IADIS eLearning 2009*, 2009. 1: 247-254

Victor, D.A. 2007. Leadership styles and bases of power. [online] Available at: <http://www.referenceforbusiness.com/management/Int-Loc/Leadership-Styles-and-Bases-of-Power.html> Accessed: 18 May 2009.

Wu, J. 2000. Accommodating both Experts and Novices in One Interface. [online] Available at: <http://www.otal.umd.edu/UUGuide/jingwu/> Accessed: 08 October 2009.

Xu, A. 2000. Eye-tracking study on identifying and analyzing user behavior - eye movement, eye fixation duration and patterns - when processing numeric table data in electronic PDF format. Masters Paper. UNC School of Information and Library Science.

Yin, R.K. 2003. Case Study Research Design and methods. 3rd ed. Applied Social Research Methods Series, Vol. 5. Thousand Oaks, California. Sage Publications.