A Web-based Human Computer Interaction Audit Tool To Support Collaborative Cognitive Ergonomics Within Interaction Design

M. Patterson, R.R. Bond, M. Mulvenna, C. Reid, F. McMahon, P. McGowan
Ulster University
Belfast, N. Ireland
{m.patterson | rb.bond | md.mulvenna | ci.woodside | fc.mcmahon | p.mcgowan}@ulster.ac.uk

K. Cowan, H. Cormican
Cirdan Imaging Ltd.
Lisburn, N. Ireland
{kcowan | hcormican}@cirdan.com

ABSTRACT

There are many user interface design and development principles within the field of Human Computer Interaction (HCI). When implementing a project, it can often be difficult to ensure that these design principles are being considered and that a positive user experience is being achieved. This paper outlines the proposition of an interactive HCI audit tool designed to aid in the adherence to various key HCI principles during the interactive design process. It is also anticipated that this tool will enhance cognitive ergonomics within the field of interaction design by assimilating existing knowledge into prototypes for practical usage. Additionally, the tool should support team-based collaboration in working towards human-computer systems that provide a quality user experience.

CCS Concepts

• **Human-centered computing~Human computer interaction (HCI)** • *Human-centered computing~Interaction design*

Keywords

HCI; checklist; interaction design; design principles; user experience; audit tool.

1. INTRODUCTION

The purpose of this paper is to explore the potential effectiveness of using a checklist-based auditing approach in assessing HCI design. While the principles outlined in the paper have been present for a substantial period of time, it can often be difficult to apply them during the development of a digital product. It is hoped that by gathering existing knowledge into an interactive tool, adherence to these principles would increase. The paper is divided into several sections. The first section investigates work related to HCI principles and the creation of checklists used for similar purposes. The second section explains, in brief, the need for HCI principles and guidelines. The next section will outline why a checklist approach was chosen for the audit tool, the principles selected that feature in the tool, and how they were divided into categories. There is also a section explaining the development of the tool from both a design and a technical perspective, using web technologies. Finally, there is a discussion as to potential future work that could be carried out to enhance the prototype as well as the potential advantages and disadvantages of taking this auditing tool approach.

ECCE '16, September 05-08, 2016, Nottingham, United Kingdom
ACM 978-1-4503-4244-5/16/09.
http://dx.doi.org/10.1145/2970930.2979720

2. RELATED WORK

There have been several studies where usability checklists have been implemented in order to solve a particular problem or to improve the quality of an existing process. Dringus and Cohen developed a usability checklist for the improvement of Learning Management Systems (LMS) for use in online courses [2]. They carried out a heuristic evaluation of WebCT and compiled a list of usability problems. They mapped these issues to usability heuristics developed by Nielsen and Mack [3] to create a single, comprehensive list. This list can be used by instructors when adding resources to the LMS to help them consider the usability of the system, particularly for students.

UseLearn is a checklist for evaluating both the quality and usability of eLearning systems [4]. After collating a comprehensive list of usability and quality principles, they condensed the list before dividing them into 12 categories. Subsequent to carrying out an experiment using the eLearning system Moodle, they concluded the checklist to be successful for identifying usability problems.

Checklists are also successfully used in medicine. A study was carried out in an attempt to reduce the number of patients dying during surgery [5]. The World Health Organisation (WHO) published a set of guidelines to ensure patient safety during surgical procedures. Haynes et al. developed a checklist from these guidelines. Results of testing showed the death rate declined from 1.5% to 0.8% after the implementation of the checklist. This checklist was also adopted by McCarroll et al. and used to create an 'interactive computerized surgical checklist for robotic-assisted gynaecologic surgery' [6]. Use of the checklist resulted in "a significant reduction in remissions at the 30-day period without significantly impacting operating room time". Whilst this is somewhat different from an audit-based checklist, we know that checklists of all types reduce errors and quality assures the task at hand. It also illustrates the diverse contexts in which it has been implemented.

3. INVESTIGATING SOURCES OF PRINCIPLES

There is a significant amount of literature outlining various HCI principles that should be considered when designing a user interface. In order to give the tool focus, contributions from several different authors will be used.

3.1 Nielsen

Nielsen is often seen by many as a pioneer in the fields of usability and HCI. He has written extensively about the importance of usability and the need for heuristics in this field. Nielsen carried out a comparison between several sets of published usability heuristics and a database containing usability problems [7]. Through this comparison, he developed a list of nine usability heuristics; 1) visibility of system status, 2) match between system and the real world, 3) user control and freedom, 4) consistency and standards, 5) error prevention, 6) recognition rather than recall, 7) flexibility and efficiency of use, 8) aesthetic and minimalist design, and 9) helping users recognise, diagnose, and recover from errors. When working with Mack, Nielsen added an additional heuristic, help and documentation, to create a list of ten usability heuristics [8]. It is these ten heuristics that have been included within the auditing tool.

3.2 Schneiderman

In 1986, Schneiderman wrote his book 'Designing the User Interface', where he discusses various guidelines and principles for designing an effective user interface [9]. He outlines what he calls '8 golden rules' for effective interface design. He notes that these are not necessarily a definitive list, as such a list can ever truly be complete. The rules are; 1) strive for consistency, 2) cater to universal usability, 3) offer informative feedback, 4) design dialogs to yield closure, 5) prevent errors, 6) permit easy reversal of actions, 7) support internal locus of control, and 8) reduce short-term memory load.

3.3 Gestalt

Gestalt is defined as "an organised whole that is perceived as more than the sum of its parts" [10]. Gestalt psychology aims to explain why human perception views the world in this way. The first academic to discuss the theory of Gestalt psychology was Ehrenfels in his article "ÜberGestaltqualitäten" (later translated to "On Gestalt Qualities") [11]. In this article, he discusses initial ideas about the various factors, which would go towards constructing the Gestalt Laws. Substantial research has been carried out in this field, and may laws and principles have been developed based on this initial research. The main laws which have been adopted for the tool are; Law of Prägnanz [12], Law of Continuity [13], Law of Similarity [14], Law of Proximity [14], Law of Familiarity [15], and Law of Common Fate [15].

3.4 W3C - World Wide Web Consortium

In 1997, the World Wide Web Consortium (W3C) developed a set of Web Content Accessibility Guidelines (WCAG) [16]. Adhering to these guidelines is important when attempting to ensure a website or software application is accessible for as many people as possible. Those guidelines have gone through a series of iterations and improvements and, at the time of writing, are currently on version WCAG 2.0 [17]. These guidelines are split into four high-level categories; perceivable, operable, understandable, and robust. They deal with factors such as the use of colour, effective and accessible use of text, and other elements such as making functionality available from the keyboard. Factors from these guidelines have been incorporated into the HCI audit tool.

3.5 Additional Principles

There are two other laws commonly used in relation to usability and HCI. These are the Hick-Hyman Law and Fitts' Law. Both of these laws are principles based on 'Information Theory' by Shannon and Weaver [18].Hicks carried out a series of experiments to measure choice-reaction times [19]. He concluded that 'Fairly strong evidence has been obtained that the amount of information extracted is proportional to the time taken to extract it, on the average". Building on this research, Hyman also carried out several experiments to determine the reaction times to visual stimulus depending on the amount of information being conveyed by that stimulus [20]. He also concluded that reaction time was proportional to the amount of information within the stimulus.

Fitts conducted a series of experiments throughout his lifetime in order to test the human motor system and its reaction times [21][22]. The results of these experiments led to the development of a law, which suggests that there is "a linear relationship between task difficulty and movement time" [23].

4. DEVELOPMENT

After all relevant principles had been researched, a comprehensive list of principles and laws were complied. There was much consideration as to how these principles could be presented. It was clear that the authors wished to create an auditing tool which would allow for a project to be measured against these principles. It was also determined that the tool should allow for an increase in cognitive ergonomics within the field of interaction design, particularly in the design and development of digital products. Research had shown how effective checklists were in the improvement of an existing process. Therefore, it was determined that the main component of the tool would be an interactive checklist. When determining the method in which the tool could be displayed, it was established that, rather than present the principles as a single list, they could be divided into a series of categories.

4.1 Compile and Categorise Principles

When defining these categories, the sources of the principles were re-examined. Common themes began to emerge. The principles outlined by W3C all pertained to accessibility. Several of the principles outlined by Nielsen and Schneiderman also concerned the accessibility of information. Many of the principles related to the cognitive processes being carried out by the user of the digital product, and in particular about not overtaxing their cognitive abilities. A third category emerged around the theme of usability, such as providing feedback to the user. There were several principles across the various sources which dealt with errors and error management. Finally, it was felt that the Gestalt principles would be best served in their own distinct category. Thus, five categories were identified as presented in Table 1;1) Accessibility, 2) Cognitive, 3) Gestalt, 4) Usability, and 5) Error.

Table 1. Table showing categories and the principles contained within them.

Accessibility	Cognitive	Gestalt	Usability	Error
Help and documentation	Offer informative feedback	Fitts's Law	Visibility of system status	Permit easy reversal of actions
Colour should not be the only visual cue	Reduce short-term memory load	Law of Pragnanz	Match between system and the real world	Design for error
Don't avoid colour just because of colour blindness	Use both knowledge in the world and knowledge in the head	Law of Continuity	Consistency and standards	Help users recognize, diagnose, and recover from errors
Text alternatives for non-text content	Recognition rather than recall	Law of Similarity	Flexibility and efficiency of use	
Default foreground and background colour combinations provide sufficient contrast	Hick's Law	Law of Proximity	Aesthetic and minimalist design	
All functionality that is available by mouse is also available by keyboard	Avoid taxing the user's attention	Law of Familiarity		
Users can easily navigate, find content, and determine where they are	The correct use of language	Law of Common Fate		
Text is readable and understandable				
Navigation mechanisms that are repeated on multiple pages appear in the same place each time				

It is planned that the tool will be used during the design and development stages of a project to create a software application. The tool has been designed to allow a project to be set up with a blank list by a project leader. Team members can then be added to the list. The team will be able to evaluate their project against the principles outlined in the tool. The list can be saved and returned to at various points during the project. There is also a function which allows for the team members to add notes about applying the principles to their project and ensure no principles are overlooked. The main aim of the tool is to allow design and development teams to collaboratively create products that provide a quality user experience.

4.2 Creation Of Prototype

The auditing tool was developed using several web technologies. A mySQLdatabase was used to manage the data within the system such as the user information, list details, list notes, and team details. Hypertext Preprocessor (PHP), Asynchronous JavaScript and XML (AJAX), and JavaScript Object Notation (JSON) were used to transfer data between the database and the web pages.

The Bootstrap framework was used to make the system responsive across various devices. Hypertext Markup Language 5 (HTML5) and Cascading Style Sheets 3(CSS3) were used to create a webpage displaying the tool. Each principle was given a checkbox, as well as an icon pointing to an external webpage to provide more information about that principle. jQuery was used to add interactive elements to the system. This consisted of making AJAX calls and processing the data which was returned. Additional interactive features such as a filter to show checked or unchecked principles, adding team members to the list, and a facility to add notes to the list were also developed. Figure 1 shows the list page of the system. This page is used as a template to allow the user to have multiple lists for different projects. Each project has a title and description to allow them to be differentiated from each other.

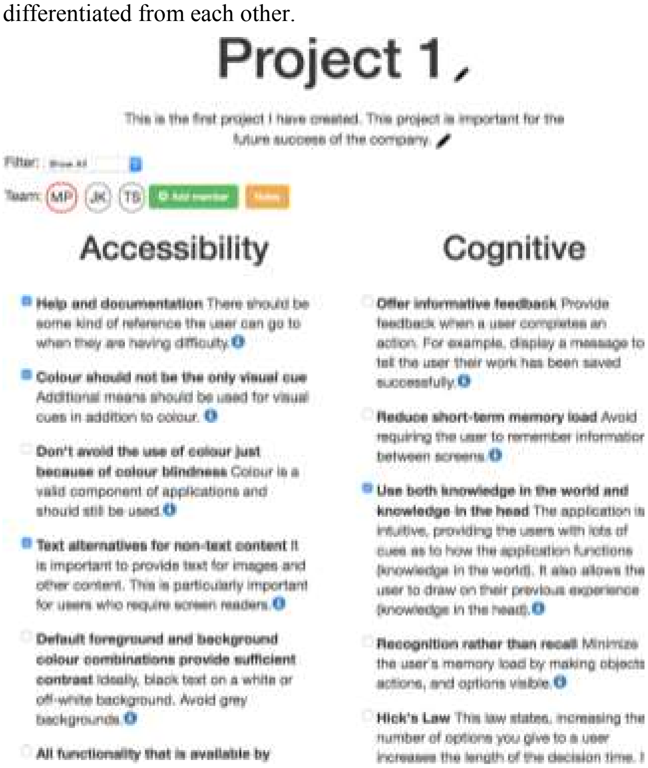

Figure 1. Partial screenshot of the interactive HCI tool.

In addition to the lists, several other webpages were developed. This allowed the user to either login or register for the system, start a new blank list, manage their current lists, and manage their account.

5. DISCUSSION

The auditing tool provides a resource which brings together existing knowledge within the field of HCI. If correctly implemented into the interaction design process, the tool should enhance compliance with the outlined principles and, therefore, result in better quality user experiences. The authors believe that this would help to improve best practices within the fields of both HCI and interaction design.

The tool should create consistency between projects and, as well as highlighting the various principles, also acts as a reference as to the implementation of each principle. The tool provides an increased awareness of both cognitive ergonomics and HCI as fields and has the potential to be used as an educational resource in this regard.

There are potential issues which may arise from the implementation of the tool. While it provides all the necessary information about the principles, it does not guarantee adherence. Indeed, it has the potential to be viewed by some as constrictive or inflexible and may restrict the implementation of some design concepts.

In terms of future development of the tool, the authors feel the first step would be to carry out usability testing with this initial prototype. This testing will help to determine the validity of the system as well as serving to identify any usability issues.

Presently, the tool has been designed primarily for use with desktop applications. In the future, it would be beneficial to develop separate lists within the tool for different purposes such as mobile development, or upcoming fields such as Virtual Reality (VR) and Augmented Reality (AR).

6. REFERENCES

[1] Olson, G.M. and Olson, J.S. (2003) '*Human-computer interaction: Psychological aspects of the human use of computing*', Annual Review of Psychology, 54(1), pp. 491–516

[2] Dringus, L. P., & Cohen, M. S. (2005). An adaptable usability heuristic checklist for online courses. *35th Annual FIE '05. Presented at the Frontiers in Education.*

[3] Nielsen, J. & Mack, R. (1994). *Usability inspection methods*. New York, New York: John Wiley & Sons.

[4] Oztekin, A., Kong, Z.J. and Uysal, O. (2010) 'UseLearn: A novel checklist and usability evaluation method for eLearning systems by criticality metric analysis', *International Journal of Industrial Ergonomics*, 40(4), pp. 455–469.

[5] Haynes, A.B., Weiser, T.G., Berry, W.R., Lipsitz, S.R., Breizat, A.-H.S., Dellinger, E.P., Herbosa, T., Joseph, S., Kibatala, P.L., Lapitan, M.C.M., Merry, A.F., Moorthy, K., Reznick, R.K., Taylor, B. and Gawande, A.A. (2009) 'A surgical safety checklist to reduce morbidity and mortality in a global population', *New England Journal of Medicine*, 360(5), pp. 491–499.

[6] McCarroll, M.L., Zullo, M.D., Dante Roulette, G., Mendise, T.M., Ferris, E., Zolton, J., Andrews, S.J. and von Gruenigen, V.E. (2014) 'Development and implementation results of an interactive computerized surgical checklist for robotic-assisted gynecologic surgery', *Journal of Robotic Surgery*, 9(1), pp. 11–18.

[7] Nielsen, J. (1994) 'Enhancing The Explanatory Power Of Usability Heuristics', Proceeding CHI '94 Conference Companion on Human Factors in Computing Systems: ACM New York, NY, USA. pp. 152–158.

[8] Nielsen, J. (1994b). Heuristic evaluation. In Nielsen, J., and Mack, R.L. (Eds.), *Usability Inspection Methods*, John Wiley & Sons, New York, NY.

[9] Shneiderman, B. (1997) Designing the user interface: Strategies for effective human-computer interaction. 3rd edn. Reading, MA: Addison Wesley Longman.

[10] Oxford English dictionary. (2007) Vol. 2. 6th ed. Oxford: Oxford University Press.

[11] Ehrenfels, C.V. (1937) 'On Gestalt-qualities', *Psychological Review*, 44(6), pp. 521–524.

[12] Scheerer, M. 1963, 'PROBLEM-SOLVING', *Scientific American*, 208, 4, pp. 118-128, Peace Research Abstracts, EBSCO*host*, viewed 3 June 2016.

[13] Fultz, J., 1999. Theory of gestalt psychology.

[14] FISHER, M., and SMITH–GRATTO, K. (1998–99): Gestalt theory: a foundation for instructional screen design. *Journal of Educational Technology Systems* **27**(4): 361–371.

[15] Goldstein, E. and Brockmole, J., 2016. *Sensation and perception*. Nelson Education.

[16] Kapsi, M., Vlachogiannis, E., Darzentas, J. and Spyrou, T., 2009. The usability of web accessibility guidelines: An approach for evaluation. In*Universal Access in Human-Computer Interaction. Applications and services*(pp. 716-724). Springer Berlin Heidelberg.

[17] W3C® (2008) *Web content accessibility guidelines (WCAG) 2.0*. Available at: https://www.w3.org/TR/WCAG20/ (Accessed: 3 June 2016).

[18] Shannon, C. E., & Weaver, W. (1949). The mathematical theory of communication. Urbana: Univ. of Illinois Press.

[19] Hick, W. E. (1953). Information theory in psychology. IEEE transactions on Information Theory, 1, 130–133.

[20] Hyman, R. (1953). Stimulus information as a determinant of reaction time. Journal of Experimental Psychology, 45, 188–196.

[21] Fitts, P. M. (1954). The information capacity of the human motor system in controlling the amplitude of movement. Journal of Experimental Psychology, 47, 381–391.

[22] Fitts, P. M., & Peterson, J. R. (1964). Information capacity of discrete motor responses. Journal of Experimental Psychology, 67, 103–113.

[23] Seow, S. (2005) 'Information Theoretic models of HCI: A comparison of the Hick-Hyman law and Fitts' law', *Human-Computer Interaction*, 20(3), pp. 315–35.