Usability Heuristics for the Design of Interactive Attention Assessment and Rehabilitation Technologies

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Abstract. Emerging technologies are beginning to find their way in different health care centers and clinics worldwide for the purpose of assessment and rehabilitation for people with attention deficit disorders. And due to the variation in the practitioners and patients' requirements and preferences for using these technologies, understanding the usability issues has become essential for further development in this domain. In particular, addressing issues of selecting usability evaluation methods and their effectiveness in identifying usability problems. A bespoke heuristic set for the context of intervention programs for developing sustained attention is proposed and tested. In this study, we conducted usability heuristic evaluations on three sustained attention assessment and rehabilitation programs that involve emerging technologies; which are Neurofeedback and eye tracking. The heuristic evaluation was conducted by five evaluators, and the results showed that the proposed heuristic inspection evaluation method was effective in finding major usability problems in programs designed for sustained attention assessment and rehabilitation. Moreover, recommendations were presented regarding the evaluators' experience with the evaluated interactive programs, the contexts of usage, target user communities, and the technical background knowledge of the interaction modalities.

Keywords: Attention · Usability · Heuristic evaluation · Eye tracking · Neurofeedback

1 Introduction

During the recent decade, a plethora of tools, methods and tests have been developed and utilized for the diagnosis and assessment of sustained attention problems in individuals, and in particular people with Attention Deficit Hyperactivity Disorders ADHD and Attention Deficit Disorders ADD. These tools and methods range from manual assessments, to more complex adaptive and intelligent computerized tests. Moreover, during the last few years, this field showed incredible increases in adopting emerging technologies for the purpose of diagnosis, assessment and rehabilitation of people with sustained attention difficulties. These technologies include: Neurofeedback detection and brainwaves analysis, Brain Computer Interfaces BCI, eye tracking, virtual and augmented reality applications. Furthermore, for the purpose of measuring sustained

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attention, there are common features that are applied and implemented in these methods, regardless of the different formats that are presented to the target patients. However, tests for measuring the sustained attention of an individual require the patient to perform a number of tasks that involve directing his/her attention to one or more targets for specified periods of time; and during this time the patient is expected to respond to a number of stimuli [1]. These responses often vary from one technology to another. For instance, in the technologies that use brain waves, the response is measured and monitored by evoking cognitive activities like concentration and paying attention, and for the technologies that use gaze interaction the response is measured and monitored by performing activities that involve directing the user's visual attention to specific areas of interest displayed on the interface. And despite the ongoing debate among researchers and scientists about the effectiveness, efficiency and the convenience of these methods, some of which are beginning to find their way in different health care centers and clinics worldwide. Furthermore, some characteristics of these methods are perceived as issues that may hinder their usability and accessibility to a wider range of audiences. These issues include availability and mobility of the method, accuracy of information that is obtained during or after the session, patient self-dependency, cost effectiveness and user entertainment. As a result, giving more insight and focus on the usability issues of the current sustained attention assessment methods and technologies is valuable for both specialists and patients. Meanwhile, usability inspection methods that address the specific contexts of attention assessment and rehabilitation are scarce. Therefore, we worked on developing a heuristic inspection method and applied it in the context of evaluating the usability of three selected sustained attention assessment and rehabilitation computer applications that use emerging technologies (i.e. eye tracking and neurofeedback) as input modalities. These selected applications are deployed for interventional programs that support users with ADHD and ADD in local service centers in Saudi Arabia. The usability heuristic evaluation was conducted by a number of evaluators who had prior experience in assistive technologies' usability evaluation and Human Computer Interaction (HCI) design experience. The aim was to examine the usability issues with such methods that adopt emerging technologies and determine the efficacy of the proposed heuristic inspection method for these technologies. In heuristic evaluations, the evaluators often review the methods/technologies, and then determine their compliance with pre-defined usability principles known as heuristics. However, this evaluation method tends to focus on identifying problems in interaction with technologies rather than solutions [2]. Nonetheless, it is often considered effective when combined with other usability evaluation tools and when conducted by subject-matter experts [3].

The remainder of the paper is organized as follows; first we describe the study design and the three selected interventional interactive programs that have been evaluated in the study. Following that, we provide an overview about the participants who conducted the usability heuristic evaluations. And then we describe the usability evaluation sessions followed by the obtained results and discussion. Then we conclude the paper in the last section with implications of our key findings on the design of interactive sustained attention rehabilitation technologies.

2 Study Design

Three attention assessment and rehabilitation programs were selected for evaluation. These programs were characterized as interventional programs which are designed with persuasive aspects and novel interaction modalities. Persuasive technologies are designed with behavior modification strategies that promote healthy behaviors [4]. These technologies are often designed in a way that ensures behavior changes and user's likelihood of long-term adoption, as noted by [4]. And considering the fact that the custom and more specialized heuristic is more effective and can reveal more usability issues, we adopted the list of specialized heuristics for persuasive health technologies developed by [4]. This list is comprised of 10 heuristics that have been shown to be effective in finding more relevant usability issues related to the persuasive aspects of the technologies being examined when compared to the basic heuristics of [2]. In our adaptation, we made some modification on these heuristics to make it more applicable to the nature of the attention assessment and rehabilitation technologies. The revised set of persuasive health heuristics is listed in Table 1.

Furthermore, it is noted that all the three programs examined in this study have been developed and designed as serious gaming systems for cognitive/behavioral therapy purpose. Therefore, we examined the gaming usability heuristics and guidelines that could be adopted for evaluating the usability of the three selected programs. Authors in [5] have developed heuristics for evaluating the usability of children's e-learning applications that involve games for educational purposes. Four of these heuristics were perceived to be relevant to the cognitive rehabilitation games. Also, they were found to be complementary to the persuasive health technologies heuristics described in Table 1. The revised subset of gaming heuristics is described in Table 2. Also, we referred to the work in [6] which includes general principles and guidelines for the accessibility and usability of educational gaming environment for students with disabilities. These principles have been combined in an aggregated usability heuristics set, specific to the context of attention assessment and rehabilitation technologies. This was used to ensure comprehensive coverage of heuristics for persuasive health aspect, serious gaming, and accessibility for users with disabilities.

3 Technologies Under Evaluation

In this study, we selected three therapeutic programs for sustained attention assessment and rehabilitation. One of them involves neurofeedback as a main input modality to control objects in a number of games designed for users who have difficulties in concentration and sustaining visual and auditory attention. The other two programs use eye tracking technologies to control objects in therapeutic games designed for users with ADHD or ADD. In the following subsections, we provide a brief overview about each program.

Table 1. Persuasive health technology heuristic

1- Appropriate Functionality:
• The technology functionalities should meet usability, mobility and visibility of target users' needs; considering the settings in which this technology might be used in
• The technology should function effectively in the user's own environment and allows the daily use as part of an individual life's routine
• The technology functionalities should be exactly reflecting the purpose that it has been developed and intended for without any extra features that might confuse the target users
2- Not Irritating or Embarrassing:
• The technology devices shouldn't irritate or embarrass the target users during the usage
• The technology shouldn't be embarrassing when it is present in the users' environment
• The technology should be easily customized in order to fit the different needs of the target users
3- Protect Users' Privacy
• The technology should allow the users to keep their information private
• The technology should allow the users to define which information can be shown and shared with others
4- User Motivation
• The technology should provide frequent feedback that indicates the progress in the user's behavior in order to meet the target goals
• The technology should use positive motivation strategies to promote the user's progress
5- Usable and Appealing Design
• The interface design should be simple and adhere to the basic usability standard with main consideration to the different usability and accessibility needs of the target users
• The interface design should be attractive and appealing promoting more user interest and engagement
6- Accuracy of Information
• The technology should obtain an accurate and comprehensive user's data
• The technology should avoid any misrepresentation of the data because of inability to use the device in one of the environments or due to certain user's conditions
7- Appropriate Time and Place
• The technology should provide the information and the feedback in effective way that helps the users to achieve the intended purpose
• The technology should provide the help when and where needed
8- Visibility of User's Status
• The technology should keep the user updated and informed about his progress toward the goals by using appropriate feedback
• The technology should provide accurate clear feedback that easily understood by the users
9- Customizability
• The technology should allow the user to customize some aspects of the technology to create personalized settings/goals
• The various interface components can be customized by switching its visibility to on or off according to the different users preferences

(*Continued*)

Table 1. (*Continued*)

• The technology implies cultural aspects by considering the diversity of its users. Including the different languages, race, gender, etc.
10- Educate Users
• The technology should increase the user understanding of the actions that led to his/her cognitive abilities improvement, by knowing which behavior leads to the target goal
• The technology should allow the users to learn all the information and skills that are relevant to the intended goals

Table 2. Gaming heuristics

1- Multimedia Representations
• All information should be presented in a variety of multimedia format: such as text, audio, and video… etc.
• The multimedia representation should assist the rehabilitation process
• The games should provide sound and visual feedback which are meaningful, and give hints that evoke emotions
• The system should avoid unnecessary multimedia as they may confuse the user
2- Use Appropriate Hardware Devices
• The games should be designed in a wide range of input/output devices
• The devices should be easily customized to suit the different users' capabilities
• The devices can be used effectively for their intended purpose
• There should be consistency between the motor effort needed to interact with the device and the user skill
3- Challenging the Users
• Enough information and guidelines should be available and provided in a clear way before starting the games, so users can start playing the game with full knowledge and confidence
• In the games, there should be different difficulty levels, so the user has greater challenge when he/she upgraded and moved from one level to the next one
• The game challenging levels should consider the users' different cognitive abilities
6- Evoke Mental Imagery
• The games should allow the user to evoke his/her imagination during the interaction with the different games elements in a way that support the cognitive rehabilitation process
• The games should encourage the user to use his/her own interpretation of the different games context and characters which increase his/her motivation toward the games' goals
• The games should be designed based on an interesting story/plot

3.1 Play Attention (Neurofeedback)

Play Attention is one of the programs that was designed for children and adults with attention problems. It has been used globally in different environments such as health care centers, clinics, schools and homes [7]. It uses neurofeedback technology that allows the user to control the elements of computer games with cognitive activity involving attention. The main concept in this technology is that when the user is actively paying attention, the brain generates streams of brainwave signals that are

processed to interact with the interface. These signals are monitored by the system's body-wave armband or headset that transmits the signal wirelessly to the computer, so the user can interact with the games [7]. The Play Attention program aims to develop the patients' abilities to focus, filter out distractions, and improve memory skills. Therefore, the program has been designed and built with several games that train the user to develop the skills mentioned earlier. This program is designed for PC platforms, and the setup involves having the user to wear an armband or a helmet to allow the program to monitor his/her brainwaves.

3.2 Tarkeezy (Eye Tracking)

Tarkeezy is a cognitive/behavior therapy PC program with games controlled through movement of the eyes [8]. It has been designed to help users with ADHD to improve their focus, attention, learn how to ignore distractions and decrease impulsive behavior. This program facilitates controlling the games by using eye tracking technology instead of using the mouse, keyboard or joystick. The eye tracking device provides an insight into what the individual is looking at, and facilitates controlling the screen objects if the stability of eye gaze remains above a predefined threshold [8].

3.3 Attentive I (Eye Tracking)

Attentive I is a cognitive therapy game designed for users with ADHD and ADD. It was developed to improve the visual attention of users and strengthen their visual memory skills with gaze-based serious gaming scenarios. Gaze-based technologies enable the users to use their eyes as an input modality to control the objects in the games. Also, the program generates reports that help specialists in tracking patients' progress [9].

4 Participants

The number of participants who conducted the expert heuristic inspections and evaluation was five. Four of them evaluated Tarkeezy and Attentive I programs. And three evaluators applied the heuristic inspection method on the Play Attention program. The evaluators experience ranged from 1 to 6 years of experience with HCI design and/or usability engineering. All evaluators had prior experience in applying heuristic inspection methods in the design and development of assistive technologies.

5 Evaluation Sessions

To evaluate the three attention assessment and rehabilitation programs, a heuristic template sheet was created. However, for every program the evaluator received a sheet that contains the list of the heuristics along with their corresponding descriptions. The evaluators were requested to indicate the severity rating for every usability issue

identified. The severity rating is used to identify the range of usability issues for these technologies and to examine the most serious usability problems in depth. In this study, we followed Nielsen's severity scale recommendations [10]. Nielsen suggested to have 0 to 4 rating scale as it is shown in Table 3.

Table 3. Severity scale

Rating	Description
0	I don't agree that this is a usability problem at all
1	Cosmetic problem only: need not be fixed unless extra time is available on project
2	Minor usability problem: fixing this should be given low priority
3	Major usability problem: important to fix, so should be given high priority
4	Usability catastrophe: imperative to fix this before product can be released

The evaluator can specify the usability severity rating based on a combination of three factors [10]:

- The frequency of the problem: Is it a common problem or rare?
- The impact of the problem: Is it easy for the user to overcome this problem and continue using the program or is it preventing him/her from completing certain tasks?
- The persistence of the problem: Is it a one-time problem (assumption is that once users are aware of the problem, they will know how to overcome it), or will users repeatedly be bothered by this problem?

All the severity rating scale details and factors' information were presented and discussed with the evaluators before starting the evaluation sessions. All the evaluation sessions followed a consistent scenario to control for variations in inspections.

First, the evaluators took part in a briefing session that was comprised of a description about the purpose of the study, the duration of the session and the method that will be used during the evaluation. In this briefing, it was ensured that a succinct explanation of the heuristic list and the severity rating scales were presented and discussed prior to examining the programs. Following that, evaluators were handed the heuristic sheet to obtain a quick overview of the list and the response recording methods. Next, a brief description about the program under study was provided. This included the main purpose of the program, its target user population, the environment that the program is intended for, and relevant specifications and features used in these programs. During this phase, the evaluators were allowed to observe and examine the devices or hardware peripherals such as the eye tracker device. After that, a demo of the software program was provided covering all the gaming scenarios. The important features and design considerations were highlighted during the demo to give the evaluators more insights about the program's objectives (especially if the evaluators did not have prior experience with the interaction modality or hardware). In addition, other materials and resources were provided during the session such as videos that demonstrate the usage scenarios of the program by the target user population. Furthermore,

screen shots for the different program interfaces were presented and discussed to highlight design objectives. After the demo, a Q&A session with the evaluators is conducted so as to give the evaluators the chance to raise any questions or concerns about the software programs or the technologies that are being examined. Following that, individually, each evaluator completes the heuristic sheet with the usability issue (s) that they identify. During this phase of the evaluation, the evaluators are allowed to go through the program's interfaces, re-examine the videos or presentation slides to recall cues or issues noted in the interface, specifications, or scenarios of the gaming programs. Once all the evaluators are finished, the debriefing session is conducted and evaluators are given the opportunity to discuss their views and findings with the other evaluators. In the debriefing session, all the usability issues that have been identified and their severity rating are shared and discussed; and the lead evaluator notes variation in views and assessment. Findings and usability issues from all the evaluators were consolidated and combined in one list. Priority listings, based on the frequency and severity ratings were collated and described in Sect. 6.

6 Results

After conducting all the evaluation sessions using qualitative heuristic usability inspections, the key findings were compiled and classified into two main categories usability problems and issues, and usability strength points.

The usability problems have been identified with severity ratings ranging between 0 and 4. And the usability strength points have been identified by indicating the area that supports the skill-development ot rehabilitation purpose for users with sustained attention difficulties. The usability issues that have been identified were listed, and their corresponding severity ranged from cosmetic problems to major usability issues. Furthermore, variation on the evaluators' opinions in determining the severity level was noted. For example, in the evaluations of the Play Attention system, two evaluators reported that the systems' hardware (either the headset or the armband used for detecting and monitoring the brainwaves) were perceived as obtrusive. This was especially relevant for the armband that needs to be wrapped tight around the arm to ensure sufficient readings. The severity rating of this issue was defined as a cosmetic problem with a severity score of (1) by one evaluator, while other evaluators rated it as a minor usability problem with a severity score of (2). Evaluators also seemed to agree on heuristics that were considered as clear and concise; for example, two evaluators indicated that the program doesn't support the local language which is the Arabic language under "Customizability" heuristic and noted that this is could cause some difficulties with non-specialized users who don't speak other languages other than Arabic language. Moreover, for the two programs that use eye tracking technology as a main input modality, the effectiveness and accuracy of the eye tracker device was one of the main issues that were identified by the evaluators. However, evaluators varied in their perception of how this influences usability based on their familiarity with eye tracking technologies. This was evident in the assessment of the "Appropriate Functionality" heuristic where two evaluators indicated that the eye tracking device's functionality and its quality of detection were influenced by several factors (e.g.

changes in the environment illumination, the need to have fixed position for the device during the interaction with the games). Furthermore, three evaluators stated that the availability of the eye tracker device is considered a usability issue. The device's cost was perceived as prohibitive; hindering its accessibility and limiting its availability to healthcare clinics or specialized rehabilitation centers. All the three evaluators found this as a major usability problem with a severity score of (3). The specific heuristics related to daily usage of the technology for patients and users facilitated a succinct description of the scope of usability assessment of this aspect of interaction. Evaluators were also requested to note strengths of the interactive systems to address the insufficient support of solution discovery by heuristic evaluation. For example; one evaluator reported that the two programs, Tarkeezy and Attentive I, effectively considered the cultural aspects in their design; considering the Arabic language and cultural-inspired elements in the games, since the programs are designed for users with ADHD/ADD in the local context of Saudi Arabia. In Table 4 we summarized all the usability issues that were identified after conducting the heuristic evaluation sessions.

Table 4. Heuristic evaluation results

Severity	{0}	{1}	{2}	{3}	{4}	Total
Play Attention	1	5	9	7	0	22
Tarkeezy	2	0	13	14	1	30
Attentive I	0	0	9	13	2	24
Total	3	5	31	34	3	76
Percentage %	3.9 %	6.5 %	40.7 %	44.7 %	3.9 %	100 %

7 Discussion

The analytic usability heuristic evaluation method has revealed a comprehensive list of usability issues in this study. This method was conducted by a relatively small group of five evaluators, who examined three sustained-attention assessment and rehabilitation programs and judged their compliance with two sets of usability heuristics. The majority of the usability issues that have been identified were considered major usability problems with a severity score of (3), which accounted for approximately 44.7 % of the total usability issues identified. This is followed by minor usability problems that had a severity score of (2), which accounted for approximately 40.7 % of the total usability issues. The cosmetic problems were about 6.5 %; and the usability catastrophe-rated type of problems were reported at 3.9 % of the overall usability issues. These results have been obtained from five evaluators; 4 of them were in Tarkeezy and Attentive I evaluation sessions, and 3 evaluators took part in the Play Attention evaluation session. It is noted that the number of evaluators was an important factor for conducting effective heuristic evaluations as it seems to impacts the quality and accuracy of issues identified during the session. According to [11], the recommended number of evaluators in heuristic evaluations is between 3 and 5. Furthermore, the combined group of evaluators is able to find the largest number of usability problems, which is often more than 50 % of the total usability problems found [12].

In the evaluations reported in this study, it is noted that the problems were mapped to the heuristics by directly checking the program's compliance with the heuristic or by relying more on the evaluator's prior experience with the software or the technology that was examined. It was interesting to note that the evaluator's prior experience with a specific program seemed to influence the type of the usability issues identified. For example evaluators who had experience with the product seemed to uncover more minor usability issues and reported more usability issues ranging in severity scores (0-2) than major usability issues. In contrast, evaluators with little or no experience with the products reported less minor usability when compared to experienced users, and were able to identify major usability problems with severity scores (3-4). Table 5 lists the total number of usability issues in relation to the evaluators' experience level.

Table 5. Usability issues per evaluators' experience

Evaluator	Experience	Number of Programs Under Evaluation	{0}	{1}	{2}	{3}	{4}
E1	High	3	3	8	15	9	0
E2	Low	3	2	0	14	22	4
E3	Low	2	4	5	12	12	2
E4	Medium	2	5	5	7	3	0
E5	Low	1	2	1	1	3	4

We found that this result could be obtained because the evaluators who have experience with the product and who were involved with the software development team are more aware of the technical limitations on the design or in the technology that led to some usability issues. Thus, the evaluators either didn't see it as usability problem or they identified it, but with low severity score. In contrast, authors in [13] found different results in a case study conducted to assess the complementarity and convergence of heuristic evaluation and usability testing. During the study, they conducted heuristic evaluation on a software product by two evaluators with different experiences. And the results showed that the evaluator with more familiarity with the product/tool tended to identify more major usability problems than the other evaluators who were less familiar with the product/tool, and seemed to be focused more on minor usability problems. They stated that this result has been found because the evaluator, who had previous exposure to the software and know its development details, may have lower sensitivity to minor usability problems.

The severity of the usability issues that have been obtained after conducting the usability evaluation sessions are listed in Table 4. The majority of the issues identified are the most serious problems with 44.7 % and the minor usability problems were about 40.7 %. Thus, in this study the heuristic evaluation generated a comprehensive list of the most serious problems within the evaluated programs in addition to reporting a large number of low priority problems. This result is in-line with previous findings reported in [12] and [13] who have noted that the heuristic evaluation method is a cost effective method that can find the most serious problems with the least amount of effort. In addition, heuristic evaluations are widely known for their ability to generate large

number of low priority usability problems. Authors in [12] stated that the loosely structured methods like heuristic evaluation can find many usability problems that are considered minor problems which may not the high important to correct. In general, during the heuristic evaluation, the HCI specialist studies the software different interfaces deeply and then searches for properties that lead to usability problems. As a result, heuristic evaluation often falls short in identifying positive findings. Notably, authors in [13] highlighted that the main aim of heuristic evaluation is to identify key problems in interacting with the systems. To address this concern, during our study, the five evaluators were asked to identify usability problems as well as strength points or positive aspects of the design that effectively support the specific objective of cognitive rehabilitation. These strength points were effective in eliciting design recommendations for developing sustained attention assessment and rehabilitation programs.

8 Conclusion

In this study, we conducted usability heuristic evaluations for three sustained attention assessment and rehabilitation programs that involve emerging technologies of Neurofeedback and eye tracking. A heuristic evaluation inspection method was introduced in the context of sustained attention technologies and applied by a team of HCI specialists. The majority of the usability issues that have been identified with this inspection method were major usability problems. The aggregate heuristic evaluation method was found to be effective as a tool for usability inspections of sustained attention assessment and rehabilitation systems and technologies. Findings suggest that this method was effective in identifying usability issues that affect the users' performance and acceptance. However, two factors emerged that seem to impact the rigourin eliciting design recommendations and uncovering interaction problems, that we have noticed during our study. First, recruiting specialized evaluators with HCI experience and familiarity with the contexts of usage of these technologies is important to achieve insights mapped directly to the contexts of usage. Second, understanding the specifications of the hardware and software involved in these systems was found to be essential to facilitate rapid and accurate identification of the usability issues related to user experience and the developed product's functionality. Future work involves applying the bespoke heuristics on iterative software development cycles of sustained attention rehabilitation software using brain-computer interfaces,

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