Evaluating user experience with respect to user expectations in brain-computer interface games

H. Gürkök, G. Hakvoort, M. Poel

Human Media Interaction, University of Twente, Enschede, The Netherlands

h.gurkok@utwente.nl, gido.hakvoort@gmail.com, m.poel@utwente.nl

Abstract
Evaluating user experience (UX) with respect to previous experiences can provide insight into whether a product can positively affect a user’s opinion about a technology. If it can, then we can say that the product provides a positive UX. In this paper we propose a method to assess the UX in BCI systems with respect to user expectations. We demonstrate the application of our method in a preliminary study. The study results showed that BCI game control was natural and enjoyable despite the low reliability of the BCI. However SSVEP based selection induced fatigue on participants. The proposed method can extract the right and wrong practices to employ BCI in applications and can suggest interaction paradigms or considerations to follow when developing BCI systems.

1 Introduction
Evaluation of user experience (UX) in brain-computer interface (BCI) systems is a relatively new practice since much of the attention has been directed to optimising performance. Nevertheless, some approaches adopted from the human-computer interaction domain have been suggested for UX evaluation in BCI systems [1]. Among the suggested possibilities, subjective evaluation through questionnaires and interviews would seem to be a promising method. The questionnaires are especially easy and comfortable to apply, suitable for extracting statistical analyses quickly, strong and reliable once validated, and applicable to the majority of BCI system users. Questionnaires make it possible to infer UX for the use of a product but they are not powerful enough to shed light on the mechanism which builds up UX.

UX is influenced by users’ values, abilities, prior experiences and knowledge as well as the context of use. Every experience a user has with a product affects not only their next experience with the product but their future experience with any product using the same technology as control input. So, a product can change the conceptions or conclusions about a technology. If the change is in a positive way, then we can say that the product provides a positive UX. BCI technology is no exception for this causal chain of UX. For example, a disabled user who has previous experience with a motor imagery based speller might have an opinion that BCI control is slow but their opinion can change positively when they use a P300 speller. However, due to the stimulation in the P300 speller, their opinion can also change that BCI control is tiresome. To give another example, for a non-disabled person, motor imagery based wheelchair control might seem to be difficult and inefficient. But when they play a motor imagery based car racing game they might consider the difficulty of BCI as a challenge they enjoy tackling. The key to success is to find the right interaction design which enables the technology to satisfy users’ needs.

As we explained above, evaluating UX with respect to previous experiences can provide insight into whether a product positively affects a user’s opinion about a technology and thus affords positive UX. In this paper we propose a method to gather user opinions (i.e. expectations) before using a BCI system and UX after using it. We analyse subjective UX ratings baselined to user expectations to explore whether the system provided a positive, neutral or negative UX. To demonstrate the application of the method, we use it to assess the UX in a BCI computer game.
2 Method

2.1 The initial method

The rationale of our method is based on the SUXES [2] method which can be used to evaluate UX in service-oriented multimodal systems. With the SUXES method, through an expectations questionnaire completed before a product is used, the acceptable and desirable levels for several dimensions of UX are collected from the user and a zone of expectations (ZoE) is identified. After the product is used, through an experiences questionnaire, the experienced level is gathered for each dimension. Then it can be determined whether the experiences are within the ZoE. We conducted a pilot study with 6 participants, applying the SUXES as is in order to test its appropriateness for BCI games. We identified two problems. Firstly, despite our best efforts in perfecting the written instructions, all the participants experienced difficulty in figuring out the mechanism of the expectations questionnaire. Even after additional verbal explanation, some participants still filled in the questionnaire incorrectly (e.g. the desired level for an item was sometimes lower than the acceptable level). Secondly, we noticed that the questionnaire items were not fully fitting for BCI systems and particularly games. For example the questionnaires asked about the usefulness of the system while in a game usefulness is not a major concern. On the other hand the items lacked dimensions such as fatigue and fun which are important for entertaining BCI games.

2.2 Adaptation of the questionnaire

In order to address the first issue we mentioned in the previous subsection, we decided to reduce the two-column expectations questionnaire design (i.e. one column for the acceptable and another for the desirable level) to a single-column one. Therefore, in our questionnaire, we use a 7-point semantic differential scale which is anchored by opposite phrase pairs at the ends (see Figure 1). The participants can then indicate their ZoE for each item by shading the box scale. Other than the phrase pairs, the scale contains no additional anchoring. We expect that if in the experiences questionnaire the user marks their experience for an item lower than the ZoE they would have negative UX and if they mark it higher they would have positive UX.

![Figure 1: Interpreting expectations and experiences: (a) implies that the user will be surprised if the interface is faster than level 4 and will be disappointed if it is slower than level 2. So the zone of expectations (ZoE) is <2,4> (b) indicates that the user rated the speed as level 4 which is within the ZoE thus meets the expectations.](image)

To overcome the second issue, based on our experience with BCI systems and particularly with games, we chose to include the following items and corresponding phrase pairs in parentheses (both in the given order), in our questionnaires: speed (slow–fast), pleasantness (pleasant–unpleasant), accuracy (erroneous–error-free), fatigue (tiring–effortless), learnability (easy to learn–hard to learn), naturalness (natural–unnatural) and enjoyability (boring–fun). Ordering of the phrases was consistent in expectations and experiences questionnaires.

3 Application of the method

3.1 The game: Mind the Sheep!

Mind the Sheep! (see Figure 2) is a multimodal computer game where the player needs to herd a flock of sheep across a field by commanding a group of dogs. The game world contains three dogs, ten sheep, a pen and some obstacles. The aim is to pen all the sheep as quickly as possible.
To command a dog, the player positions the cursor at the point to which the dog is supposed to move and they hold the mouse button pressed. Meanwhile, the dog images are replaced by circles flickering at different frequencies. The player concentrates on the circle replacing the dog they wish to select (so as to generate a steady-state visually evoked response, shortly an SSVEP). The stimulation persists and electroencephalograph (EEG) data is accumulated as long as the mouse button is held. When the user releases the mouse button, the signal is analysed and a dog is selected based on this analysis. The selected dog immediately moves to the location where the cursor was located at the time of mouse button release.

### 3.2 Experimental procedure and tasks

Fourteen people (2 female) participated in the experiment. They had an average age of 24.5 ($\sigma = 2.88$), ranging from 19 to 28 years. Four of them had previous experience with BCIs, not with Mind the Sheep!. Another group of four indicated that they played games more than 5 hours per week.

Participants sat on a comfortable chair approximately 60 cm away from a 20’’ screen with a resolution of 1280 $\times$ 960. They read the instructions to play the game while the experimenter was mounting the EEG. Before the game, based on their current knowledge and previous experiences, they filled in the expectations questionnaire to indicate their ZoE for selecting dogs using BCI. They were instructed to shade any number of boxes (between 1 and 7) they wished to, with respect to the devices they would need to use and tasks they would need to do to select a dog. After that, the experimenter collected the questionnaire, left the room and the game began. The participants played the game until all the sheep were penned or the play time reached 10 minutes. Finally, after the game, they filled in the experiences questionnaire.

### 3.3 Results and Discussion

![Figure 3: Median values across all participants for ZoEs (grey cells) and UXs (black circles).](image)

For each item, we computed the medians of the experienced levels and the lowest and the
highest expected values across the participants (Figure 3). We also computed the medians across all the items (the last row in the figure) as the indicator of overall UX. Experience levels for all items, except for fatigue, and for overall UX were within the ZoE meaning that the game provided a neutral UX. An item level analysis can provide better insight into what was right and wrong in the design of the game or the interaction. Especially the items rated beyond or on the border of the ZoE are of interest. Ratings for accuracy show that the SSVEP detection mechanism was not reliable. Despite this, experience levels for naturalness and enjoyment were on the positive end of the ZoE meaning that participants found selecting dogs by concentration intuitive and they enjoyed the gameplay. However, as the ratings for fatigue imply, they were tired by the SSVEP stimulation. These findings collectively mean that participants enjoyed playing the game using a BCI but perhaps another type of BCI, such as a stimulus independent one, could have been a better alternative.

Another research direction is to cluster participants according to their previous experience with BCIs and explore how the expectations and experiences differ between the participant groups. We performed this analysis but did not find any difference between experienced and naive BCI users. Perhaps, with a well-distributed and larger sample space interesting results can be achieved.

4 Conclusions

UX is influenced by users’ values, abilities, prior experiences and knowledge as well as the context of use. Evaluating UX with respect to previous experiences can provide insight into whether a product positively affects user’s opinion about a technology and thus affords positive UX. In this paper we proposed a method to assess the UX in BCI systems with respect to user expectations and demonstrated its application in a preliminary study. The study results showed that BCI game control was natural and enjoyable despite the low reliability of the BCI. However SSVEP based selection induced more than expected fatigue in participants. No difference was found in UX evaluations of naive and experienced BCI users although this might be due to the unbalanced and small sample space.

The proposed method can be used to determine whether a BCI system improves upon users’ previous experiences with BCIs or not. It can extract the right and wrong practices to employ BCI in applications and can suggest interaction paradigms or considerations to follow when developing BCI systems. It can also be used to study how and why UX changes for different user groups. The proposed questionnaires can be modified for use with for general BCI systems, following the method we have described. Then the method can be used for a broad range of applications (e.g. assistive, recreational BCIs) and users (e.g. patients, gamers).

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References
