A Framework for the Evaluation of Human Frustration In the Control of Cursor Movement with the Brain

Mehdad Fatourechi
Department of Electrical Engineering
University of British Columbia
283-2366 Main Mall
Vancouver B.C. Canada V6T 1Z4
+1-604-224-2530
mehrdadf@ece.ubc.ca

Kayvan Davoodi
Department of Computer Engineering
University of British Columbia
283-2366 Main Mall
Vancouver B.C. Canada V6T 1Z4
+1604-430-3391
kdavoodi@mss.icics.ubc.ca

ABSTRACT
In the past few years, the brain computer interface (BCI) systems have gained a lot of attention although they've been rather ignorant of the fact that whether the severely disabled-bodied actually would use the current BCI systems or not. In this project, we've defined a general framework for the evaluation of the human performance and human frustration in the control of cursor movement with the brain. This framework describes a new way to look at the BCI problems and that's from the user perspective. We'll show that the current BCI technology has a long way to reach the point where the users can use it. We'll also show that the proposed framework can be used in educational purposes.

Keywords
BCI systems, psychology, frustration,

1 INTRODUCTION

Development of the Human- Computer Interface (HCI) technologies has been a major research issue in the recent years. Input/Output devices related to fields such as vision, voice, etc. have been employed in the design of user-friendly and ergonomic systems. And now direct interaction between the brain and the computer adds a new challenge to the HCI: *Brain-Computer-Interface (BCI).*

Motivated by helping people with severe motor disabilities, BCI has already gained a lot of attention and several research groups have dedicated their efforts to find a way for the communication of the severely disabled patients with the environment using the brain ([3], [13]). Initial results show that the BCI systems represent a new frontier in the science and technology. However, the results are just preliminary and many questions are yet to be answered. A good review of the current trends in BCI technologies, their future perspective and challenges ahead is brought in [5].

However, although many efforts have been made in order to make good software/hardware tools and to make BCI technologies more applicable, one important aspect has not been addressed in the literature yet : *how good our system should be in order that we can commercialize it as a useful BCI device? To be more specific, what percentage of error is acceptable for our system?* The roots of this question lie in this property that "*the BCI systems are basically different from other control systems because the targets of the control system are the humans and not the plants*". In an BCI system, our main target should be to gain the satisfaction of the disabled users, and for sure, measurement of error won't be a good criterion for the judgment of our system.

This research is done in order to address this shortcoming of current BCI approaches. It is motivated by a paper with similar idea [6]. In [6], the authors introduced a method for the measurement of human frustration thus defining the higher bound of the error we are allowed in the design of a typical BCI system (in their case, a Scanning Key Board). In our paper, we address the same problem but from a different perspective. We'll focus on the control of cursor with the brain and we'll try to define a criterion for the evaluation of the cursor movement control methods. Movement is an important part of many BCI systems. Especially cursor control (as a part of interaction with the computer) is very important for the disabled humans. Communication with other people and environment are among examples that will demonstrate the importance of curser control. Although a complete test for the evaluation of an interface for "communication between the user and the computer" is much more complex and it needs more complex models, but in this project we'll only focus on the control of the cursor and modeling the action that is to be taken after the curser is moved to the desirable position, is left to the future researches.

The organization of this paper is as follows. In Section 2, we describe the BCI systems in more detail. In the 3rd section, we'll develop our proposed general framework. This section consists of three parts. In 3.1 we'll describe the problem in general and address the issue of user frustration in detail. In 3.2 the structure of the proposed experiment will be addressed and section 3.3 is dedicated to the implementation and test issues. The results of the research are brought in section 4 with the conclusions and the summary to be addressed in the 5th section.

2 INTRODUCTION TO BCI SYSTEMS

In this section we briefly address the concept of the BCI systems, their state of the art and the related challenges. Also we'll address how the current BCI systems have taken the matter of "user satisfaction" into consideration.

2.1. What is an BCI system?

A formal definition of BCI is addressed in [12]:"A brain-computer interface is a communication system that does not depend on the brain's normal output pathways of peripheral nerves and muscles". BCI systems usually use EEG signals to gather the information corresponding to the user's thoughts and then apply this information to interact with the surrounding environment. Such an interface is very useful for people with severe motor disabilities to communicate with the outside world.

A general diagram of an BCI system is shown in Fig.1, based on the general framework proposed by Mason and Birch in [11]. First, EEG signals are achieved through an experiment which is out of the scope of this research. Due to the high level of noise in this stage some amplification and pre-processing is done. Then at the next stage, feature estimation and classification is done and some mapping between features and commands takes place. Finally through the device controller, the user will be able to interact with the environment. The result of this process is a possible change the status of some device in the Environment and the corresponding signal returns back to the user via feedback.

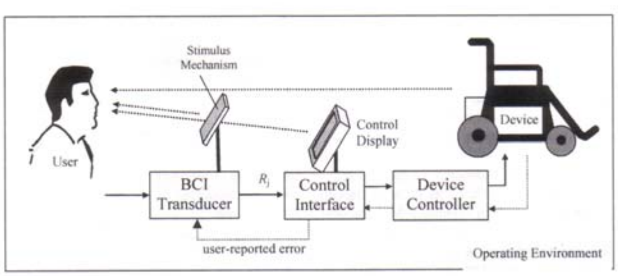

Fig.1 The general structure of an BCI system (reprinted from [11] with the permission of authors)

The key part of such an BCI system is the correct extraction of information from the EEG signals and then its translation into some meaningful command. Several BCI research groups in all around the world have focused their attention to address this matter. Among them are the Neil Square Foundation [3] and the Wadsworth Center [13]. A comparison of several features in existing BCI is brought in [1]. According to [1], surprisingly, most BCI researchers spend a little time discussing user satisfaction or do not discuss it at all. This poses a new challenge in front of us. How good our system should be in order that severely disabled bodied would actually use it? This is an important issue, because so much effort has been made to extract information from very noisy signals (with SNR < 1), without considering the fact that maybe we do not need this amount of effort at all. Maybe our goal can be achieved with a more erroneous system which is at the same time more practical. Or maybe the percentage of acceptable error for some particular application should be so little that the existing approaches are far from applicable. There is apparently a missing link here and that's the measurement of the ***user satisfaction*** (or ***user frustration***) .The example of cursor movement is just a simple one. A more sophisticated control movement could be the control of the wheelchair when even a low error rate may lead to catastrophic results.

These discussions lay the necessary foundations for the evaluation of the current BCI systems based on the criterion of user satisfaction/frustration (or the evaluation of user performance in general).

In the next section, we'll discuss our framework for the assessment of user satisfaction in BCI systems.

3 THE PROPOSED FRAMEWORK

In this section we describe the proposed framework for the measurement of BCI-caused frustration for the users trying to control cursor with the brain. Because such measurement is task-dependant, the results obtained here can not be generalized to other tasks (such as wheelchair control, typing, etc.) but they can be accounted as the first step towards developing a general framework for the evaluation of BCI-caused frustration in the movement control.

3.1. Understanding the User Frustration

User frustration in the use of technology has always been a persistent problem. Hardware and software problems and poor user interfaces trigger confusion for the users. If we do not take user satisfaction into consideration in the design of HCI systems, then our efforts would become in vain. Only when the interface is satisfying, we can expect success from our proposed system. Hence, in recent years, a number of researchers have paid their attention to addressing this important matter in the field of HCI ([2]-[8]). In this section we take a look at the general findings regards HCI caused frustration.

When does frustration occur?

Frustration occurs when there's an inhibiting condition, which interferes with or stops the realization of a goal. The level of the frustration experienced by an individual clearly can differ, depending on the circumstances surrounding the experience and on the individual involved. One major factor is goal commitment, i.e. the determination to try for and persist in the achievement of the goal ([4]). The importance of the goal to the individuals and the strength of the desire to obtain the goal, will affect the level of the goal-commitment as well as the strength of the subsequent reaction to the interface failures.

Frustration caused by the computer interfaces

Many possible HCI related problems could be named which build frustration in the user. From hardware problems, to software bugs and poor interface, they can all cause losing the work, wasting the time and frustrating the user. In the context of the social and psychological research literature, frustration occurs when users can not attain their goals ([2]). The factors that can subsequently affect the level of the frustration experienced fall into two categories: the incident and the individual factors ([2]).Incident factors include *Goal commitment, the severity of the interruption and the importance of the goal:* self-efficacy and the importance of the goal affect the commitment to the goal. When a failure occurs, the level of the goal commitment and the time lost will affect the amount of the frustration experienced by the users.

The main parts of individual factors are: *anxiety (*the level of the user's comfort with the HCI systems and how the subject reacts when facing a problem with the HCI system). And *Mood/ Psychological factors (*how often subjects get upset over things and general mood).

As it can be clearly seen, frustration is a complicated psychological phenomenon which is affected by several factors. What we'll do in this research, is providing the first steps towards addressing user frustration in the BCI systems.

3.2. The Experiment setup

3.2.1. The Model

The structure of the experiment setup is shown in Fig.2. The basic idea of the game (which is a simplified version of the Pacman game) is that the user starts the game in the position (x). Using four arrow keys he should go from his initial position to the place where the target (a cherry, but we call it the target from now on) lies and eat it. For the simplicity, we have only considered four basic directions

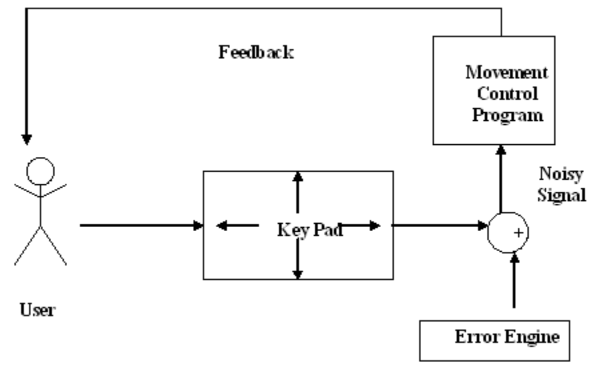

Fig.2. the Experiment Setup

(North, South, West and East), thus mimicing the movement of the cursor .The user should reach its target as fast as he/she could and eat it, then the current target disappears, the user gets the score and another target appears in the game. This procedure continues and the user continues to score. The end of the game is specified by the number of the movements that the user has taken; this number is fixed for all the users and it's determined through pilot testing. Also in order to increase the level of the goal commitment, the target disappears every "A" time slots, so time is also an important issue here. Here the criterion for the success of the user is the amount of his score, so basically we've devised a task-based approach instead of a time-based approach. The reason that we've not used the time-based approach is that in the time-based approach it's possible that we would not be able to test the real amount of error on the user, for example the user behaves so slow that only a few movements can be made before the time of the experiment gets finished.

The current game, apart from its role in the study of the user frustration, has another benefit which is also very important from the BCI systems design point of view and that's the *Educational purposes.* Currently, the benchmarks of BCI systems are very simple. Introducing a simple game which is especially designed for BCI, can be used as an educational tool for increasing the level of the goal commitment of the user.

3.2.2 Modeling the Error

Now we describe modeling the types of errors that usually occur in current BCI systems and then we add them as the sources of noise to the control commands .These sources of noise are modeled as "Error Engine" part (Fig.3) which adds error to the arrow key address that our program reads from the key board, Resulting in two major errors which can be described as:

False Positive (FP) Errors: when the user wants to put some particular command into the action, but because of the errors generated in the preprocessor/classifier blocks the system instead applies another command, we say that an FP error has occurred. In our model When an FP error occurs, the system totally ignores the user command and selects another command from the remaining two

False Negative (FN) Errors: this type of error happens when the user sends a command but nothing happens. The reason is the wrong mapping between the command and a point outside the selection space, thus our system performs a "do-nothing" command. In our system, when an FN error occurs, the system completely ignores the user command and keeps the Do-Nothing state and waits for another command from the user.

The other type of error that can happen in our system is *False Command (FC).* This type of error happens when the user has not sent any command but the system "translates the noise to some action". This type of error is also very annoying, because it changes the state of the user from the "Do-Nothing" state to "Command" state unwillingly. However, in most of the current applications of BCI, called "synchronize" systems, the design is such that the system doesn't respond to signals during the "idle" time (or do-nothing period) so there's no FC in such systems. In another group of BCI systems called "asynchronous systems" [3], we can allow commands during the idle times, but the designers are careful to keep FCs as low as possible (FC<1%). Accordingly, we left this parameter out of the scope of design, which also was helpful from the statistical point of view because it reduced the number of independent variables in the system.

3.3. Implementation and Testing

The Code of the game is written in Java. Java provides us with an environment with both graphical and computational capabilities. we should take one thing into consideration: the reason of the design of this game. We want to study the user frustration not creating a fantasy game to play. Also the game should be designed such that it can be run in similar circumstances. Designing games with different levels of complexity prevents us from a scientific study.

As for the testing, two options can be considered as the measurement of the user frustration: getting feedback from the user using the measurement of vital signs (ECG, EEG, Blood Pressure, etc.) This method gives more accurate results regards physiological changes in the subject but it can not give information about Mood/psychological factors. It also needs complicated technology so we won't discuss it here. The other method is measurement of user frustration using questionnaires. In this method, the user fills out questionnaires during the experiment, describing his/her status. This method is less reliable because of the possible forgetfulness or the user willingness to lie. But it has the advantage of taking both incident and individual factors into consideration. As the community of study grows larger, errors caused by lying or forgetfulness also become less important [2].

A good way to study the user frustration in our case is what can be called as a "Trial diary method" instead of a survey. Trial diaries (special case of time diaries) minimize the reporting burden on the respondents by allowing them to record the result of each experiment immediately after it ends instead of attempting to remember a large amount of information after the survey. This is the approach that we've used here.

The Experiment: Here we considered three levels for each error (0% ,10%, %20 of the overall movements), so in the best situation the system has 0% error and at the worst case, it has 20% FP and 20%FN resulting in the total of 40% error. This is also consistent with the current methods which have total error rates lower than 50%.

The procedure of the experiment is as follows: Before the Start of the Test Session the coordinator of the experiment describes the whole structure of the game for the subject and guides the subject through filling out the forms. The subject fills out the pre-session questionnaire, then starts the game from the initial state (the overall error is zero) and plays the game for three times. After finishing the introductory phase, the subject fills out the after-trial session questionnaire. Then the experiment begins: the error is selected randomly from the space of the possible amounts. The subject plays nine times with different error types. After each session, the user fills out the after-trial form describing how he/she feels. The coordinator gathers data from all the subjects and does the statistical analysis.

The questionnaires are designed in a way that the subject does not get biased by them. Hence, indirect questions were included in After Trial Session questionnaires so that we do not address the user frustration directly.

4. RESULTS AND DISCUSSION

Before we discuss the results, it's important to account some facts about the experiment:

1) Before the start of the main experiment, we did pilot study on two healthy male students and we found out that setting the total of moves to 150 and the time of the disappearance of the cherry to 10 seconds are acceptable for our study. Also although we had designed the game in such a way that it could be played both in 1-D and 2-D but the pilots stated that the 1-D experiment was very boring. So based on their feedback, 1-D experiment was omitted. Also we'd designed the game so that the movement can be made either by "step by step" or "continuous" movements. In "step by step" mode, each time that the user presses a button, the Pacman is displaced only a few pixels but in "continuous" mode, the Pacman continues its way unless another command is placed. Again, the results of the pilot study showed us that the pilots were strongly against "step by step" mode, so we did the experiment in continuous mode.

2) We performed the experiment with only 10 subjects. The test pilots and the experimenters were not included as the subjects. Also because of the small number of subjects available, we had to switch from “between subjects experiments” to “within subjects experiments” [10], meaning that we performed all the tests on each user.
3) Each subject study took between 35 to 45 minutes.
4) We randomized the order of the games that each subject had to play, so the user had no idea what to expect in the next experiment.

In section 4.1, we’ll remark our observations during the experiments.

4.1. Observations

During the tests, most subjects showed signs of frustration: signs like biting their lips, harder pushing the arrow keys, and shouting remarks were observed on different subjects. Although most subjects didn’t report these signs, but they showed that the current system was at some times successful in increasing their level of the frustration. Also most of the subjects began to complain during the last couple of runs. Although we randomized the order of the experiments, and thus prevented the effect of the tiredness to be shown on certain choices of errors, but this is a very important matter to be considered in the future experiments. Also, in order to increase the level of the “goal commitment “of the game, we included a “high score” on the starting page of the game. So that it gives more motive to the subjects to actually beat the high score and print their name. Unfortunately, except three subjects, which two of them also became successful on beating the high score, the subjects did not pay attention to this feature of the system.

4.2. Analysis of the Experiment

In this section, we’ll discuss the findings of the experiment in detail.

4.2.1 Demographic Information

Seven subjects were male and three were female. All except one in their twenties and university students. The 10th subject was a high school student.

4.2.2 Pre-session Survey

As for the experience with the Pacman game, four subjects didn’t have any previous experience and the remaining six had experience between 5 to 15 years.

In order, to fill out the forms, we designed the question as statements such that each subject had to state whether he/she was in agreement or disagreement with that particular statement based on seven choices ranging from (-3) indicating “strongly Disagree” to (3) indicating “Strongly Agree”. We asked the subjects that had previous experience with the Pacman game, whether they found this game enjoyable or not. The average response was “agree” with the STD of “1”, so we can conclude that the population of subjects more or less liked the “Pacman game” regularly, and this is important from the “goal commitment point of view”.

We also asked the subjects to state their opinion with regards to the following statement: “When I run into a Game Over when playing a game, I feel frustrated”. Except one subject who strongly disagreed with this statement, others gave responses from “neutral” to “agree”, resulting in the average response of “0.9” which is roughly equal to “mildly agree”. This result is also important from the “goal commitment” point of view, because it shows that most subjects were sensitive to some extent to the matter of “Game Over”.

The subjects then were asked about their “mood” before the experiment so that we compare it with the results after the experiment. It turned out, that although some experiments had magnificent effects on subject’s mood (especially the ones with higher error rates); these question could not catch the real effect of the experiment on the subject. Here, the average answer was “1.5” which stands at the mid-point of “mildly agree” and “agree” with STD of “1.2”which means overall, the subjects were in relatively good mood prior to the experiment.

4.2.3 after the Initial Trial Session

The purpose of assessment of initial trial by means of “After the initial trial session” survey was to get the opinion of the subjects regards the game in general. We wanted to make sure that the game was not frustrating by itself. As we stated earlier, our goal was to keep the game as simple as possible, so that the subject could just focus on the game

For the statement “This game was easy”, here is how the subjects answered this question: the mean was “2.3” with the STD of “1”, which means that the subjects generally were in agreement that this was an easy game to play. This is very important. If the answer to the question lied someplace between “0” and “-3”, it meant that the game itself was challenging, and then it could become a hard task to identify the effects of the errors on the performance of the subject.

1. In answer to the statement “I liked the design of the GUI”, the average was “1.5” with the STD of “1”. The conclusion: although we designed a very simple GUI for the system, the subjects kind of liked it (they chose an answer between “mildly agree” and “agree”). Which is good news; because it means that this simple design could meet the expectations of the subjects to some extent.
2. In answer to the statement “I liked the scenario of the game”, the average response was “1” with STD of “1.26”. This means that the subjects were less fond of the scenario of the game. Here the results were also more scattered. This was also expected by us; compared to the fantasy games

that are in the market today, with complicated scenarios and very graphical GUIs, the scenario of our Pacman game doesn't stand at a high point. Maybe adding some complexities in the future, makes the scenario of the game more likable by the subjects, and at the same time preserves our original goal of modeling the cursor control.

3. In answer to the statement "Overall, I find this game very interesting", the mean response was "1.3" with the STD of "0.78". None of the subjects chose an answer between "mildly disagree" and" disagree", which is encouraging by itself, because it means that the subjects were interested in playing the game.

4.2.4 Results of After Trial Session

For the analysis of the performance of the subjects, we used two methods. One was saving the results of scores of the subjects and the other one was the post-session questionnaire. The first method is vital because it gives us information which is achieved from the subject indirectly and it is not dependant on the subject intentions. The second method is important because it gives us information regards subjects' experience during the study.

We used the average "score" of the game as the measurement of the performance of the subject in different situations. This is an interesting issue, because we have to know the effect of the errors of the system on the performance of the user. In fig.3, we've plotted the distribution of the mean of the performance of the subjects compared to the 0% FP and 0% FN situation as the index of the highest performance. In order to better visualize the results, we plot their distribution in 2-D as indicated in figure 3.a. Also the standard deviation of the data is shown in figure 3.b. The rough distribution of the performance in the 3-D space is shown in figure 3.c.

Based on these charts the following observations can be made:

Ob.1. The errors had significant effect on the performance of the subjects. If we look at the fig 3.a again, we can easily find out that even the low error rates of (FP=10, FN=0 or FP=0, FN=10) force the performance of the subjects to drop below the 80% of their performance in the ideal situation (when no error was present) which yields the Conclusion that the performance drop is more than the error generated by the system. At the extreme case of (FP= 20 and FN=20), the performance reaches to the point of 35% which means that we've a drop of 65% in the performance with only 40% of error. Also the distribution of the STD shows that except two cases of (FP=20, FN=0) and (FP=20, FN=10), in the other cases, the STD is about or below 10. This means that we have a relatively good confidence that performance dramatically changes with the error.

Ob.2. Our findings here didn't show much difference between the performance drop related to FPs and performance drop related to FNs. this is mainly because of the uncertainties introduced in the system by the low number of population of the subjects as indicated by the STD. Although increasing the number of subjects will help to clarify this matter, there's another important factor that it's worth stating. In order to increase the level of the goal commitment of the system, we introduced the time as a factor that encourages the user to act faster, which based on our pilot studies and also the observations during the experiment, was a very important positive step. But now that the target vanishes after certain amount of time and

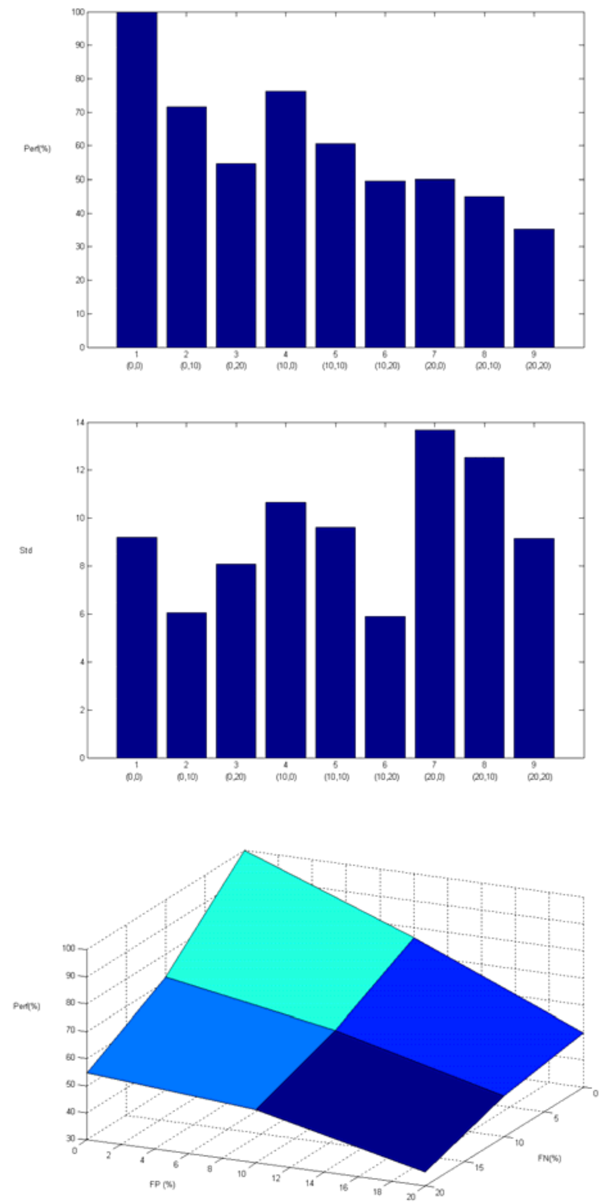

Fig.3. a) average for (FP, FN) b) std for (FP, FN) c) 3D presentation of the average

appears in another part of the surface, it's possible that the FP command actually guides the Pacman towards it based on pure chance. If we had omitted the constraint of time, such a thing probably would not have happened and we'd better model the movement of the cursor but with the lower level of goal commitment. So there's a compromise here.

Now let's discuss results obtained in the After Session Questionnaires:

a) In answer to the statement "I felt some errors in the movements", the average of responses in 2-D is plotted in figure 4.The low STD that we obtained in this question, shows great harmony between different subjects. In fig.4, except the case of (FP=0 and FN=0) which naturally the subjects answered with the "disagree" response, in other situations , the responses were between "agree" and "strongly agree", which shows that even slight error rates of 10% were very much noticeable by the majority of the population, although the std of the data shows that there was some disagreement between the subjects with regards of the amount of the error they felt in the special cases of FP=10, FN=0 and FP=0 and FN=10. But for total error rate of more than 10%, the subjects were nearly in the position of "strongly agree" to the statement, and as we see in the special case of (FP=20% and FN=20%) all the subjects without exception, felt the errors in the system strongly.

b) In answer to the statement "The errors generated in the game prevented me from reaching the target", the average of responses in 2-D is plotted in fig.5.The results in this section are also similar to the results in the previous section, but this question is targeted at a very important issue, and that's how much the subjects see the errors as barriers in reaching to the target. The results in fig.5 show that the average population has a position between "agree" and "strongly agree" that the errors generated by the system prevented them in reaching the targets. Also the STD of the data shows that for the total error of more than 10%, subjects were in strong agreement that the errors had negative effect in their effort to reach the targets. From another point of view, this shows that the subjects had to "struggle" in order to counterbalance the effect of the errors. These results are significant in the design of BCI systems since they show that error rates more than 10% are strong barriers by subjects which prevented them from reaching their goals.

c) We also asked the subjects' opinion about the statements "I find the experiment enjoyable", and "my mood is happy". The results however showed the low reliability of the current data because of the large amount of STD especially in high error rates. But the average of responses showed that the trend of the responses is from "agree" to "disagree" with the increase of error. These results show that we're on the right track and hopefully

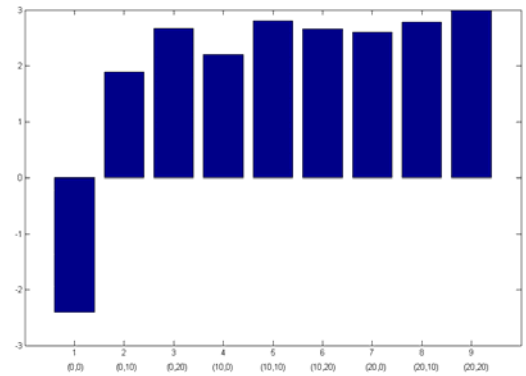

Fig.4. the average of the responses for (FP, FN)

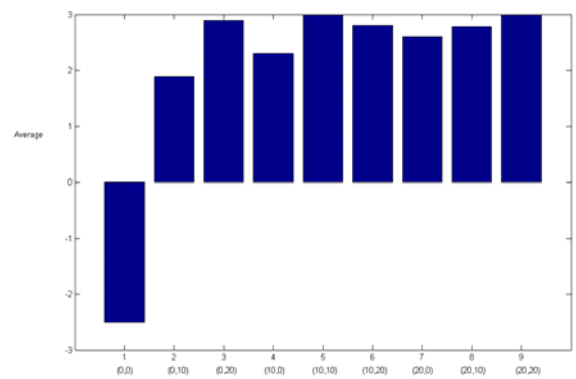

Fig.5. the average of the responses for (FP, FN)

larger pool of subjects will yield more trusting results.

The last question was aimed at addressing why the particular experiment was enjoyable or was not enjoyable for a subject. Except two cases of an error-free system and a system with FN=10, in all the other cases the majority of the subjects mentioned the errors as the primary source of why they did not find the experiment enjoyable. This is the only place in this study that the feedback of the subjects in the case of FN=10 was significantly different with the case of FP=10, but it needs further investigation to make a solid conclusion.

In summary, it's obvious that the errors caused by the system, turned an enjoyable experiment into a rather non-enjoyable one, especially in the case of high error rates (if we want to be cautious in using the "frustrating" term). This was the ultimate goal of the experiment. We wanted to express that in the design of BCI systems, there are other factors which should be taken into consideration besides the absolute error and as we saw, even in the case of relatively error rates, subjects showed the signs of uneasiness even in the short periods of having experience with our system.

4.3. Comments for Future Works

1) As we mentioned in 4.1, some subjects showed signs of frustration, although they didn't report them. That's one of the basic problems with filling the questionnaires as we mentioned earlier. They're sensitive to the human error, especially with a small pool of subjects. Thus for future researches, we strongly suggest the measurement of the some of the vital signs of the body like blood pressure. Including the score in the current experiment, was a first step to include the parameters that are not based on the questionnaires.

2) Larger pool of subjects is a must be for reaching solid results in this experiment. Although the current experiment sheds some light on the matter of studying user frustration, deriving a general hypothesis needs more subjects.

3) The current experiment is designed based on the hypothesis that there is no particular delay between the successive commands. Although this is an ideal situation for BCI systems but that's not the case for current systems. So modeling the delay between commands makes the current model more appropriate for the study of the current BCI systems.

4) Modeling the FCs also will generalize the model to "Asynchronous Systems".

5. CONCLUSIONS

In this project, we designed an experiment for the measurement of the user frustration in the BCI systems. The experiment consisted of a Pacman-like game in 2-D space. In order to model the common errors in BCI systems, we introduced two types of errors in the system, false positives and false negatives. We studied the effects that these error had on the performance of the user, and how much tolerance do the users show with respect to different kid of error rates. The results show that error rates bring the performance of the subjects significantly lower and they're felt as strong barriers which prevent the subjects to reach to the goals. We also presented some guidelines for the future user studies to make this project more applicable The results of this preliminary study showed that the current situation of BCI systems with the maximum performance of up to 65% are far from applicable as interfaces for severely disabled people. Specifically, because the users of the BCI systems are usually disabled patient with severe motor disabilities they are probably more sensitive to the errors caused by the system than the ordinary healthy users.

ACKNOWLEDGEMENT

We would like to thank Dr.Sid Fels for his valuable guidelines throughout this project. We would also want to thank Dr. Gary Birch and Dr Steve Mason for providing the information related to BCI systems.

REFERENCES

[1]Bayliss, J.D., "The flexible brain-computer interface", PhD thesis, University of Rochester, 2001.

[2] Bessiere, K. , Ceaparu, I., Lazar, J., Robinson, J., and Schneiderman, B., "Understanding Computer user frustration: Measuring and Modeling the disruption from poor designs", Technical Report: University of Maryland, Sep. 2002.

[3] Birch, G.E. and Mason, S. G. ,"Brain-computer interface research at the Neil Squire Foundation", IEEE. Trans. Rehab. Eng., Vol.8, June 2000, 193-195.

[4] Campion, M., Lord, R., "A control system conceptualization of the goal-setting and changing process", Organizational Behavior and human performance, no.30, 1982, 265-287.

[5] Ebrahimi, T. ,Vesin, J. M. , Garcia, G. "Brain-Computer Interface in Multimedia Communication", IEEE Signal Processing Magazine, Vol.20, No.1, Jan.2003, 14-24.

[6] Forrest,G., Zikov, T., and Zhou, Y., "Evaluation of an asynchronous switch application using frustration metrics for potential use in Biological driven switches (especially EEG)", proceedings of HIT coneference,2002.

[7] Klein, J., *Computer Response to User Frustration.* **,** MIT Masters Thesis, Feb.1999.

[8] Kling, R., "Learning about information technologies and social change: the contribution of social informatics", the information Society, Vol.16, no.3,, 2000, 217-232.

[9] Locke, E. A. and Latham, G. P. , *a theory of Goal Setting and task performance,* Englewood Cliffs, NJ, Prentice Hall, 1990.

[10] Martin, D. W., Doing psychology experiments, Brooks/Cole Publishing Company, 1984.

[11] Mason, S. G. and Birch, G. E. , "A general framework for brain computer interface design", IEEE. Trans. Rehab. Eng, in Press.

[12] Wolpaw, J. R. , Birbaumer, N., McFarland , D. J. , Pfurtschellar, G. , and Vaughan, T. M. ,"Brain-Computer interface for communication and control", Clin. Neurophysiol. vol.113, 2002, 767-791.

[13] Wolpaw, J. R. , McFarland, D. J. , and Vaughan, T. M., "Brain Computer interface research at the Wadsworth Center", IEEE Trans. Rehab. Eng., Vol.8, June 2000,222-226.