Moods and programmers' performance

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Abstract. We tested the impact of mood on the debugging performance of programmers. Four movie clips were used to induce programmer's mood. In the test, 72 programmers watched both a neutral video clip and one of the four mood evoking video clips and after each of these they took a debugging test. Examination of the test results revealed an almost significant effect for the arousal mood-dimension on both debug score (F (1, 70) = 3.33, p = 0.07) and on the number of questions attempted within the required time (F (1, 70) = 6.26, p = 0.015). However, no significant effect was found for the valance mood dimension. These results seem to suggest that the programmer's ability to find and correct errors in program code depends on their level of arousal.

1 Introduction

Throughout our daily life we experience a series of different moods. We feel saddened by the death of a friend, whilst feel joyful and happy on the birth of a child or at a wedding. Similarly, in almost every task from flying a plane to performing an operation or programming a real time system, one would expect to feel a wide range of positive and negative feelings [6]. These feelings and moods may cause disruptions in our daily tasks. These disruptions along with interference in energy, sleep, and thinking are common, painful, and too often fatal [7]. It has been found that moods affect various different activities of people like creativity [8,9], memory tasks [10], reasoning [11], behavior [12], cognitive processing [13], information processing [14], learning [15], [16], decision making [17], [38], and performance [11,18,19].

The Merriam-Webster dictionary defines performance as the ability to fulfill a job. The main objective of this study is to consider the performance of the programmers in the context of their moods. According to a survey conducted in 2006 by PK500 (a quarterly survey of business and HR professionals) 86% people believe that their performance at work is related to their mood [2]. These responses were collected from over 200 people in a wide range of organizations in the United Kingdom. Ekman [20] argues that moods affect thinking, narrows alternatives, can make it difficult to perform tasks, and may affect performance indirectly while someone is at work as moods make it difficult to control what we do. Erber and Erber [21] stated that there is a threat to the performance of tasks if individuals seek to repair bad moods. Although there is considerable work regarding moods and performance, it seems that researchers have spent less time in exploring the role of emotion and mood in relation to information technology (IT) professionals [22]. Impacts of affect on behaviors have also been under the study of recent psychology [23] but research on the impact of moods on the IT professionals seems lacking [24].

Our study tried to fill this gap. As evident from literature, mood affects reasoning, which is an essential element of programming. For example, Jones [25] stated that testing alone is not sufficient to verify the validity of a computer program, without reasoning about its behaviour. Programmers should specify the logical structure and flow of the program first on paper, before implementing it. The suggestion of a link between emotion and reasoning is not new, as Damasio [26] makes a strong argument that emotions and reasoning are interrelated. Likewise, the impact of moods on reasoning is also evident from [27] and [28]. Therefore, if moods have an impact on reasoning then they might also have an impact on a programmer's performance.

This study examined the impact of moods on programmer's coding and debugging performance. The study used an experimental set-up in which programmers were asked to complete a debugging test after watching a video clip that was selected to elicit a specific mood. Before this experiment, a study was conducted to select these mood-inducing videos, and to develop the debugging test. The following paragraph will first provide a brief discussion about the concept of emotion and mood.

1.1 Moods and emotions

The Merriam-Webster dictionary defines emotion as "The affective aspect of consciousness, a state of feeling, a conscious mental reaction (as anger or fear) subjectively experienced as a strong feeling usually directed toward a specific object and typically accompanied by physiological and behavioral changes in the body" and defines mood as "A conscious state of mind or predominant emotion". Both moods and emotions are considered as affective states [48]. Moods are assumed to be affective states that tend to last a little longer and are weaker states of uncertain origin, whereas emotions last for a short time, are more intense and have a clear object or cause [49]. Moods can last from a day to sometime two days or more whereas emotions come and go in minutes and sometimes even in seconds [50]. Most psychologists consider mood and emotion as the same entity. For example Dow [51] consider mood as a type of emotion. Most studies also use the terms mood and emotions interchangeably without differentiating between them see, for example [52, 53]. According to Ekman [50] mood is a continuous emotional state, whereby moods differ from emotions on the basis of the time they are retained and on the variation in the intensity. Furthermore, given an emotion, it is possible to identify the events that caused it, however the event responsible for causing a mood is rarely known. Moods can just happen for example; one can wake up in a morning with some particular mood. Zimmermann et al. [54] stated that moods may result in preconceived emotions as people may not be aware of their moods until attention is drawn toward their mood.

1.2 Two-dimensional valence-arousal mood model

Valence is defined as the degree of happiness or sadness whereas arousal is defined as a subjective state of feeling activated or deactivated [62]. The representations of valence and arousal on X-axis and Y-axis form a two-dimensional model as proposed by Lang [61]. Fig. 1 below explains some affective states and their correspondence to some valence-arousal combinations. For example the “Rejoice” state could be mapped as very pleasant and high aroused whereas “gloomy” could be mapped as unpleasant and low aroused. Similarly “terrified” could be mapped as unpleasant but high aroused whereas “soothing” could be mapped as pleasant but low aroused [62].

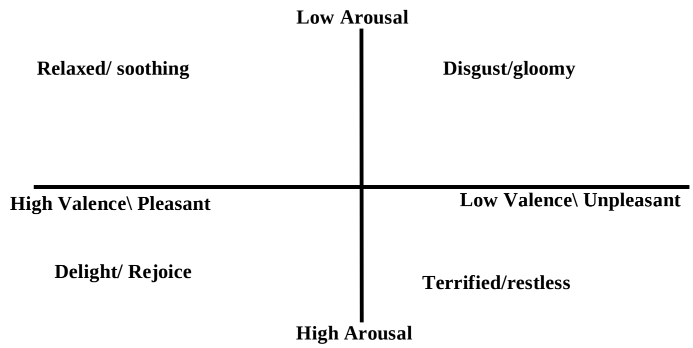

Fig. 1. Valence-arousal model with some examples of moods/emotions

Although there are researchers who believe moods to be discrete in structure and trace it back to Charles Darwin’s theories, there are various other researchers who consider moods as dimensional [30]. An in-depth discussion about discrete versus dimensional moods is provided by Remington and Fabrigar [31]. The use of two-dimensional models to examine mood is gaining increasing acceptance [29]. Various researchers consider mood as, at least, a two-dimensional construct, with an evaluation (valence or pleasure) dimension and an arousal dimension. For example, Almagor and Ben-Porath [32] divided two dimensions as arousal/activation dimension and hedonic tone/pleasantness dimension. Others like Morris [33] prefer an additional third dimension to express the dominance (controlled, un-controlled). This study used only a bi-dimensional model, with the two dimensions: valence and arousal as these two dimensions are primary and are used in most emotional judgments [37].

The objective assessment of moods on valence arousal model was done using the SAM [55] scale. This scale is often used in research that applies self reporting measures. SAM has been presented as a promising solution to the problems associated with measuring emotional responses [33]. SAM represents PAD (Pleasure arousal Dimension) along a nine point scale using graphical characters. For pleasure/valence the figure ranges from smiling happy figure to frowning unhappy figure. For arousal the figure ranges from excited open eyes to sleepy closed eyes. Fig. 2 shows use of this scale along X-axis and Y-axis. Horizontal X-axis scale starts from 1 (High Valence) to 9 (Low Valence). Similarly vertical Y-axis scale starts from 1 (High Arousal) to 9 (Low Arousal).

2 Experimental material

The experiment[1] involved five movie clips to induce moods and a multiple-choice questionnaire (MCQ) to measure a programmer's performance on recognizing debugging problems. The following sections will discuss how the validity of the experimental material was examined prior to the experiment.

2.1 Validating the debugging test

We collected 24 C/C++ multiple-choice questions[2] from a textbook on C++ [36] in order to assess the performance of the programmers. All the questions were multiple-choice questions with three or four answers. MCQ tests are used extensively for assessment purposes in courses such as computer programming and physical education [39], and therefore, potential participants would be familiar with this type of questioning. Including questions in the test from different levels of difficulty ensured that the test was able to measure debugging performance of programmers with different levels of expertise. The difficulty level of the questions was based on assessed using: The chapter number and the position of the questions in the exercise and on the difficult, medium and easy rating by three lecturers from a computer sciences department.

The selection of questions was based on the assumptions that the initial chapter's questions might be easier than later chapters' questions because of the introductory nature of the initial chapters. Similarly a question appearing at the start of the exercise might be easier than one at the end of the exercise. Three lecturers also rated the level of questions from easy, medium and difficult. Table 1 shows the strategy that was followed in the selection of two sets of six questions out of the original set of 24 questions. For example, the questions that received an easy rating from all lecturers were always selected. Some easy and medium questions were also selected if two lecturers agreed and the third lecture gave questions a rating on one level higher or lower. All questions rated as difficult by any of the rater were also filtered out, as there was only one question selected as difficult by all three raters. All other difficult ratings were not close matches. The two sets of 6 questions were used to create two debugging tests, both including three easy and three medium level questions. Finally, these questions were translated into C#, Java and Visual basic dot net, allowing programmers to take the debugging tests in their preferred language.

[1] The experiment can be done by visiting http://uxisfyp1.brunel.ac.uk/cspgiak/

[2] Download debug questions from http://mailtoiftikhar.googlepages.com/moodvalidation

Table 1. Criteria for the selection of questions of the debugging tests

Criteria for the question selection	Number of Questions	*Selected/Not Selected*
Rated as easy by all lecturers	4	All 4 selected as easy
Rated easy by 2 and medium by 1	7	2 questions selected randomly
Rated as medium by 2 and easy by 1	6	All 6 selected as medium
Rated as difficult by at least by 1 lecturer	5	Due to difference in rating by all lecturers none selected
Total Question	24	

2.2 Validating the movie clips

We used movie clips to induce moods. Mood induction procedures are widely used in various research including [38,40,41]. For a detailed discussion of the mood induction procedures see [42]. We selected a set of 14 movie clips from different online sites and sources based on their content to represent a specific quadrant. For example one of the selected movie clips from the movie "Dead Poet Society" shows a death scene and mourning by the dead person's friends. We expected that this movie clip will represent low valence and low arousal. We selected all other movie clips on the similar assumptions for the particular quadrants. To test the required mood induction nature of the movie clips, we carried out a mood validation experiment.

A total of 10 student participants (age M = 26.40 years; SD = 2.41; age range from 24 to 30; 2 females; 8 PhD students; 2 Masters Students; 8 with programming experience) participated in the study. The duration of each movie clip was from 3 to 4 minutes, and after each clip, they rated their mood on the two dimensional nine-point SAM scale [55].

Based on the average ratings of the movie clips we selected four movie clips for the experiment as shown in the Fig. 2. Each clip represented one of the four quadrants by having the largest Euclidean distance from the mid point. Additionally a neutral clip was selected, which had the smallest Euclidean distance from the mid point (Valence=5, Arousal=5). The rating of these clips was compared with each other. The neutral movie clip was excluded from this comparison as it was used as a control reference point in the experiment. The 95% confidence intervals as apparent from Fig. 2, indicate that there is no significant difference between movie clips of similar valence or arousal quadrants. However there was a significant difference between movie clips in opposite valence or arousal quadrants.

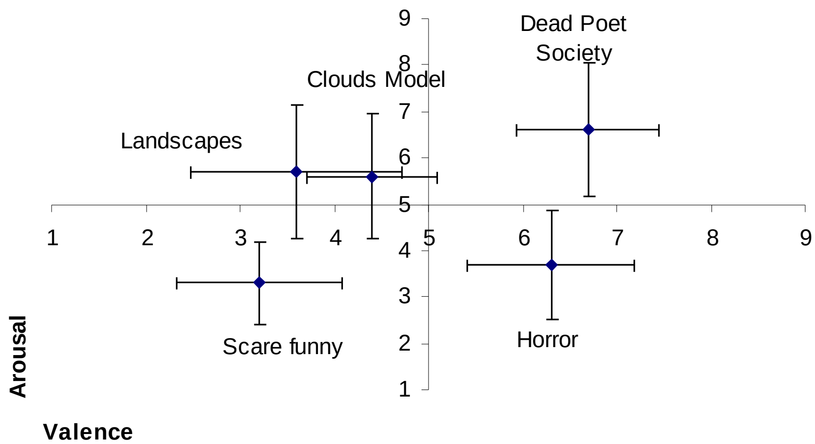

Fig. 2. Average mood ratings of the 4 selected mood inducing video clip and the mood neutral video clip (Clouds Model).

3 The Experiments

The experiment was conducted on the internet. The results from a web experiments and surveys seem quite similar to the similar settings in a laboratory environment despite great differences between the subject characteristics [3]. We decided to perform the experiments on the web as we needed the involvement of professional programmers, which is difficult to obtain. The web experimentation gave us the solution as web experiments are generalizeable demographically (participants represent targeted population), generalizeable in different situations and have high external validity (not in a controlled environment and depicting original behavior). They are also time generalizeable (can be taken at any time at participant convenience), costs are low, there are greater statistical powers (the participant pool is almost unlimited in size) [3]. A detail discussion regarding web experimentation can be found at [4].

3.1 Participants

Data was obtained from 372 cases in which people started the experiment; however in only 75 cases was the experiment completed. Three out of 75 participants indicated that they had done the experiment at least twice. Therefore the analysis was done on 72 cases in which participants took the experiment for the first time. Five participants were females. Their age ranged from 18-44 years with a mean of 26.31 and SD of 5.23. Programming experience ranged from 0.5-25 years with a mean of 4.81 years and SD of 5.55. Participants included 80.6% professionals, 8.3% postgraduates, 5.6% undergraduates, 4.2% PhD students, and 1.4% hobby programmers. Participants who used C/C++ were 58.3%, 23.6% used C#, 11.1% used Java and 6.9% used Visual basic dot net..

3.2 Procedure and Experimental Design

The experiment was conducted on the Internet. Invitations to various programmers' platforms were sent and some programmers received a direct invitation. When entering the test the participants first saw an introduction page, which explained the nature of the experiment and requested the participants to give their consent for participating in the experiment and the collection of data. After this participants went through a training session in which they became familiar with the sequence of the test which consisted of watching a video clip, followed by a series of MCQ that they had to answer within a fix time set, and finally participants were asked to rate their level of arousal and valence on the SAM scale [33]. After completing the training session, participants continued with the actual test, which consisted of two cycles of the movie - debugging test - mood-rating sequence. There were two fixed debugging tests of six questions. The movie clips were either the neutral movie clip, or one of the four mood inducing movie clips. To control for potential training effects, the order of the neutral movie and the mood movie clip as well as the selection of the specific mood movie clip was systematically controlled. The system assigned participants in cycles of eight to the eight possible sequences (four clips, two orders for each). Furthermore, the assignment of the two versions of the debug test to the first or the second cycle was counter balanced.

The overall time to complete the debug test was limited in order to ensure that the effect of the movie clip persisted through the test. Every question had a separate timing which was allocated on the basis of the length of the text and the number calculation involve. For example if a question contained 10 lines of code then this question was allocated 70 seconds. Similarly a question involving computation like (x= 2 + 2 * 10 / 2 – 2) was allocated 50 seconds although it only contained one statement. Questions involving simple debugging and syntax were allocated only 30 seconds. An example of this type of question is as follows

```
Q. Identify and correct the error(s) in the following:

if ( age >= 65 );

cout << "Age is greater than or equal to 65" << endl;

else

cout << "Age is less than 65" << endl;

Options
```

```
1.        No Error
2.        'Else' not properly used
3.        Semicolon after if
4.        Both 2 and 3
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If participants answered the question before the time deadline, they would move to the next question in the test.

4 Results

The first step in the analysis was to conduct a multivariate analysis to see whether the movies had an impact on the performance of the debugging test. To control for individual level of debugging expertise, the analysis was done on the difference between the performance after seeing a neutral movie and a mood invoking movie. A MANOVA was conducted with as dependent variables: the difference in the number of correct answers in the debugging test and the difference in the number of questions where participants did not need the maximum time set for questions. The results of the analysis revealed no significant main effect for valence (F (2, 67) = 1.43, p = 0.25) and arousal (F (2, 67) = 0.25, p = 0.78) and also found no interaction effect (F (2, 67) = 0.34. p = 0.72) between these two factors.

Table 2. The number of particpants that were randomly allocated to mood invoking videos

		Arousal		
		Low	**High**	**Total**
Valence	**Low**	7	14	21
	High	31	20	51
	Total	38	34	72

The second step in analysis was to analyze the raw performance data without considering the performance of the participants when they saw the neutral movie. A similar multivariate analysis as in step one was conducted. Again no significant results were found for valence (F (2, 67) = 0.67, p = 0.52), arousal (F (2, 67) = 1.65, p = 0.2), or interaction effect (F (2, 67) = 0.84, p = 0.44) between these two factors.

Potentially the small number of participants that were randomly assigned to the low arousal low valence movie (Table 2) might have limited the power of the two-way multivariate analysis. As arousal had the smallest p-value, two separate one-way ANOVAs were conducted with this factor as independent variable. The results of the ANOVA on the number of correct answers in the debug test revealed an almost significant effect (F (1, 70) = 3.33, p = 0.072) for arousal this time. As can be seen in Fig. 3, participants gave more correct answers after seeing high arousal movie clip (M

= 3.09, *SD* = 1.75) than after seeing the low arousal movie clip (*M* = 2.37, *SD* = 1.60). Fig. 3 also shows that performance after seeing the neutral movie clip was somewhere in the middle (*M* = 2.88, *SD* = 1.56). Likewise a significant effect (F (1, 70) = 6.26, p = 0.015) for arousal was also found by the one-way ANOVA on the number of questions where participants did not need the maximum time set for questions. Fig. 4 shows that after seeing the high arousal movie clip (*M* =4.21, *SD* =1.63) participants more often gave an answer and pressed the 'Next question' button than after seeing low arousal movie clip (*M* = 3.11, *SD* =2.05). The performance after seeing the neutral movie clip (*M* = 4.00, *SD* =1.68) again is in the middle of high and low arousal movie clip. Although violation of the normality assumption of ANOVA might have a very limited effect on the final results [63], a non parametric Mann-Whitney U test on the number of correct debug answers found an effect for arousal with a *p*-value (z = -1.736, p = 0.083) which approaches again the 0.05 α-level. Similarly a Mann-Whitney U test on the number of questions answered in time revealed a significant effect for arousal (z = -2.370, p = 0.018).

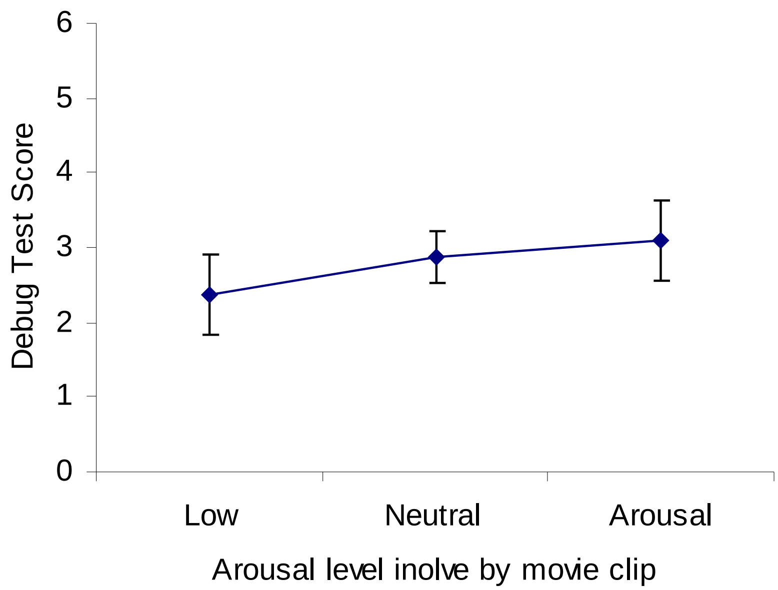

Fig. 3. Number of correct answers after seeing a movie clip with 95% confidence interval

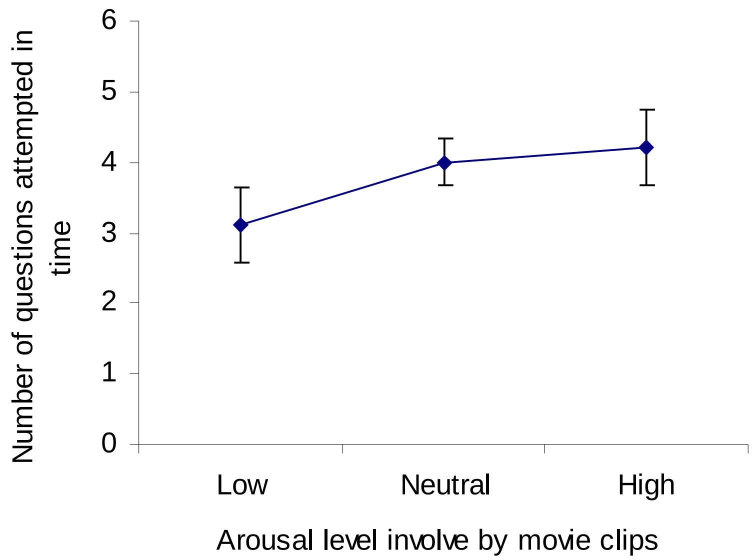

Fig. 4. Number of questions attempted with in the required time after seeing a movie clip with 95% confidence interval

5 Conclusion, Limitations and Future Research

The results of this study suggest that the level of arousal can affect a programmer's debugging performance. This finding seems to agree with previous research that also suggests that arousal is related to performance, as is expressed with the Yerkes-Dodson Law [47]. For example Strack et al. [43] trained baseball batters for six weeks to control anxiety and over-arousal and noticed a 60% improvement in their batting performance. Arent and Landers [44] found a significant quadratic trend for arousal and reaction time while riding a bicycle ergo meter. Several other studies such as [45] and [46] also found a direct relationship between arousal and performance. For a detail discussion of arousal models see [57].

As with any study, the presented study also had its limitation. A few researchers like Mandler [58] and Schachter [59] doubted the direct relationship between mood/emotions and arousal. They proposed that cognitive processes might be an intermediate factor in any arousal mood relationship. Another limitation of the study is that the tasks given to the programmers are not representative of industrial debugging where most of the effort goes on locating and identifying relevant code and ensuring the changes create no ripple effect. However this experiment shows that moods have at least an impact on programmers' debugging tasks. Further studies are needed to examine the impact of moods on performance in an industrial environment.

Various studies have showed that valence (positive and negative moods/happiness or sadness) does have an impact on performance along with various other interrelated tasks [11, 14, 60]. However in our study no significant effect was found for this dimension. The reason for this might be the limitation of an un-monitored internet experiment. An internet experiment may have control issues, self selection, drop outs (80% in our study), technical variance, and interaction with participants and comparative basis [3]. Also, the short duration of video clips (approximately three minutes) might mean that they only have a very limited impact on mood. The number of participants took the test randomly and thus watched the movie clips randomly. There is a ratio of 1:2.4 between the participants who watched low valence movie clip vs. high valence movie clip. This ratio is almost 1:1 for the arousal movie clips. This might also be a cause of no or limited effects found for valence on debugging performance. Future studies will try to reduce these limitations by conducting a similar experiment in a controlled lab environment. These experiments will form the basis for our further research in measuring moods from basic input devices including mouse and keyboard.

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