

Subliminally Enhancing Self-Esteem: Impact on Learner Performance and Affective State

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Abstract. The purpose of this work is to enhance learner self-esteem while interacting with a tutoring system. Our approach is based on a subliminal priming technique that implicitly conditions learner self-esteem. An experimental study has been conducted to analyze the impact of this method on participants' reported self-esteem on one hand and learning performance on the other hand. Furthermore, three physiological sensors were used to continuously monitor participants' affective reactions, namely electroencephalogram, skin conductance and blood volume pulse sensors. The purpose was to measure the effect of our approach on both learner mental state and emotions. We then proposed a model that links learners' physiological signals and priming conditions to learning results.

Keywords: subliminal priming, self-esteem, learning performance, sensors, learner affect

1 Introduction

Nowadays learner affect has become a key construct in Intelligent Tutoring System (ITS) researchers. Several works focus on affective student modeling [4], identifying learner emotions [5], detecting frustration and stress [23] or assessing attention levels [25]. Most of these systems use a variety of physical cues to recognize affective state [22] including observable changes like face expressions, body postures, vocal tones, and physiological signal changes such as heart rate, skin conductivity, temperature, respiration and brain electrical activity. Ultimately, these works seek to properly adapt tutorial interventions and improve learner performance.

On the other side, many educators and pedagogues advocate the benefits of self-esteem in learning. A broad strand of research investigated the positive effects of self-esteem on learner self-confidence [20]. Besides, several studies have shown strong correlations between self-esteem and academic achievement and success [12].

Recently, McQuiggan, Mott, and Lester [21] proposed an inductive approach to model learner self-efficacy. They used learners' demographic and physiological data to predict their self-efficacy level. While self-efficacy represents the individual's

belief about her ability to execute specific tasks, self-esteem is a more generalized aspect [14]. It reflects the overall personal self evaluation.

Mainly, literature differentiates between explicit self-esteem and implicit self-esteem [8]. The former is based on conscious mode of thinking and can be measured by means of questionnaires, whereas the latter is the result of automatic self-evaluative process and can be assessed with indirect measures. Unlike explicit measures which are based on generally biased self-report, implicit measures are based on unconscious attitude toward the self [8].

These latter measures are mostly used in unconscious process based researches, mainly in the neuro-psychological communities. The core of these researches is the existence of a threshold-line of conscious perception. The idea is that a stimulus below this threshold of awareness, also called subliminal stimulus cannot be consciously perceived but can yield affective reactions without awareness [6]. This technique is known as subliminal priming. It has been applied in different contexts [15] including self-esteem conditioning and learning improvement.

In this paper, we propose to integrate the implicit self-esteem component within learning process. More precisely, the aim is to condition learner self-esteem while interacting with a tutoring system, using a subliminal priming strategy. The hypothesis we establish is that this method can improve learner performance. We propose to conduct an experimental study using a subliminal priming technique.

Our research questions are the followings: can subliminal priming enhance participants' self-esteem? Can this method produce a positive effect on learning performance? Is there any effect on learners' emotions and mental states? What is the influence of learner physiological activity and priming conditions on learning results?

The remainder of the paper is organized as follows. We start by outlining the background concerning the subliminal priming approach. Next, we describe the developed tutoring system and experimental setup. Then, we discuss the obtained results, conclude and present directions for future work.

2 Previous Work on Subliminal Priming

Researches devoted to automatic or unconscious processes have increased over the last years. Their basic assumption lies on the existence of a threshold-line between conscious and unconscious perception [6]. A stimulus is known as subliminal, if it is received below this threshold of awareness and cannot be consciously reported. High-level semantic and even emotional processing has been observed during this stage [15]. Masked priming is one of the main techniques used to project subliminal information [6]. In this method, a subliminal stimulus, also called prime, is projected during very short time. The prime is preceded and/or followed by the projection of a mask for a specific time. This mask usually takes the form of a series of symbols having nothing to do with the prime in order to elude its conscious detection.

In the Human Computer Interaction (HCI) community, Wallace, Flanery and Knezek [27] implemented subliminal clues for task-supported operation within a text editor program. They found that the frequency at which subjects demanded help was much lower when the required information was subliminally presented. In another

perspective, DeVaul, Pentland and Corey [7] used subliminal clues for just-in time memory support. They investigated the effect of various subliminal information on retention in a word-face learning paradigm.

In the ITS community, Chalfoun and Frasson [3] used a subliminal priming method within a 3D virtual tutoring system. It was found that overall performance was better, and time for answering questions was shorter for learners primed with subliminal clues. Learners' emotional reactions were also different; subliminal stimuli elicited high arousal states. Hence, besides yielding better results, subliminal priming seemed to elicit emotional consequences not only in learning, but also in various other domains like: social behavior, advertisement, stereotypes, food preferences, etc. (see [15] for a review). On the other side, evidence from this body of literature indicates that this effect is more important compared to consciously perceived and reported stimulus effects [1]. A recent work of Radel, and colleagues [24] put forward an interesting effect that subliminal priming can have on motivational processes. They investigated the impact of motivational primes in a natural setting, namely the classroom. A positive effect of subliminal priming on academic performance was found; this effect was basically moderated by learner mindfulness.

In this paper, we propose to introduce a new approach to subliminally enhance learner self-esteem while interacting with a tutoring system. We are interested in analyzing the effect of this method on participants' reported self-esteem, on their learning performance and affective states. Our methodology and experimental setup are described in the next section.

3 Experimental Methodology

Materials. The tutoring environment developed for this experiment consists of a multiple choice questionnaire related to logic. The questions are typically found in brain training exercises or in tests of reasoning ability. They involve inferential skills on information series and do not require particular prerequisites in any field of knowledge. The questionnaire is composed of 3 modules. Each module is concerned with specific forms of data: the first module deals with geometrical shapes, the second module with numbers and the third module focuses on letters. In each module, learners have to answer to 5 multiple choice questions. Figure 1 depicts a screenshot of our system from each module. The idea is to try to find the logical rule between the data, and guess the missing one.

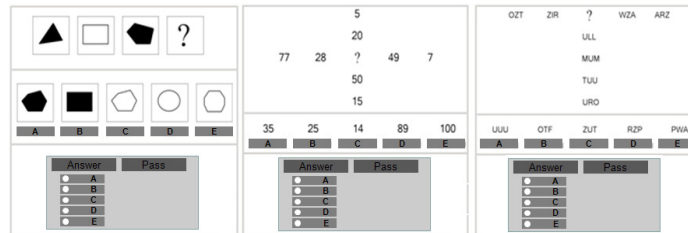


Fig.1. Screenshots from each module

Each Module starts with a tutorial giving instructions and examples to get learners accustomed with the user interface and types of questions. Learners are asked to respond as quickly and efficiently as possible to each of the 15 questions of the quiz. A correct answer was worth 4 points, an incorrect answer -1, and a no-answer 0.

3.1 Enhancing Self-esteem

In order to enhance learner self-esteem, we used an evaluative conditioning (EC) subliminal procedure [11]. This method consists in subliminally projecting self-referent words (conditioned stimulus or CS) paired with positive words (unconditioned stimulus or US). The idea behind EC, is that conditioning influences the structure of associations in memory, and hence the automatic affective reactions resulting from these associations [11]. This method has already been found to influence self-esteem in earlier experiments (e.g. [8, 11]). Besides, it has been found that EC effects occur without awareness of the stimulus pairing.

Hence, in our experiment, some participants (experimental condition), were repeatedly presented with the subliminal primes (CS and US stimuli).¹ The other participants (control condition), were not presented with subliminal primes. Projecting thresholds were carefully chosen according to neural recommendations [6]. Each subliminal prime (self-referent word and positive word)² was displayed for 29 ms preceded and followed by a 271 ms mask of a set of sharp (#) symbols.

Self-Esteem Measure. Learner self-esteem was assessed using the Initial Preference Task (IPT), [19].³ Participants were asked to evaluate their attractiveness for all letters of the alphabet on a 7-point scale. Letters were presented individually, in random order on the screen. Participants pressed the corresponding key to evaluate each letter. High self-esteem is indexed by the extent to which a person prefers his or her initials to other letters of the alphabet.

3.2 Physiological measures

Physiological measures were recorded continuously during the experiment using a ProComp Infinity encoder. Three types of sensors were used: electroencephalogram (EEG), skin conductance (SC) and blood volume pulse (BVP) sensors. (1) EEG electrical brain activity was recorded using a lycra stretch cap placed on the scalp. Cap electrodes were positioned according to the International 10/20 Electrode Placement System [16]. EEG signals were recorded from 4 scalp sites (P3, C3, Pz and

¹ In order to get learners focused on the screen, questionnaire materials (shapes, numbers and letters) were presented sequentially. Subliminal stimuli were then presented just before the materials appeared.

² Self referent words were: I, and participant's first name. Positive words were: nice, smart, strong, success, and competent. These words were selected from previous studies addressing self-esteem [10].

³ Participants were also asked to complete an additional self-esteem measure, namely the Implicit Association Test (IAT, [10]). However, since IAT yielded essentially the same results as the IPT, only the effects concerning IPT are reported. These measures were chosen according to [2] assessing the most promising implicit measures of self-esteem.

Fz). Each site was referred to Cz and grounded at Fpz. EEG signals were calibrated with regards to the average of left and right earlobe sites (A1 and A2). Each electrode site was filled with a small amount of electrolyte gel and sensor impedance was maintained below 5 K Ω . The recorded sampling rate was at 256 Hz. (2) SC sensors were placed in the 2nd and 4th left hand finger. (3) BVP sensor was placed in the 3rd left hand finger. SC and BVP data were recorded at 1024 Hz of sampling rate. Heart rates (HR) were derived from BVP signals and galvanic skin response (GSR) from SC. All signals were notch filtered at 60 Hz to remove environmental interference during data acquisition. Besides, two webcams were used to synchronize physiological signals with the tutoring system tasks. The former monitored the learner's facial activity and the latter recorded the learner's interactions on the computer screen.

Affect Recognition. From the physiological recorded signals, we wanted to analyze both learners' mental and emotional activities. In order to analyze the mental state, we used the recorded EEG signals. Indeed, neural research established various EEG-based mental states and neural indexes of cognition [9]. More precisely, EEG studies on mental concentration and attention [13] defined an EEG indicator of attention to internal processing during performance of mental tasks. It was found that an increase in the delta and low theta (delta_low_theta) activity is related to an increase in subjects' internal concentration [13]. For analyzing learner brain activity within this frequency band, we applied a Fast Fourier Transform (FFT) to transform the EEG signal into a power spectrum. We then extracted the percentage of delta_low_theta band (1.56 - 5.46 Hz) [13] from the transformed signal. We used these values as an indication of learner mental concentration while answering to the questionnaire.

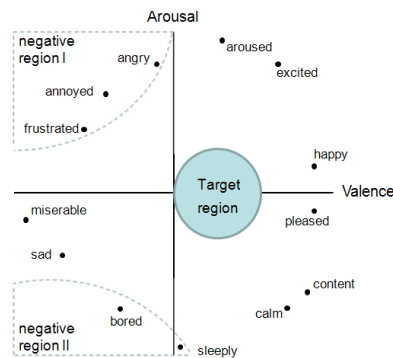


Fig. 2. Russell's circumplex model of emotions with regions

In order to assess learner emotional state we considered HR and GSR signals which are known to be correlated to valence (positive to negative) and arousal (low to high) [18] and we used Russell's circumplex model of emotions [26]. This model classifies emotions in terms of valence and arousal dimensional spaces. Two strategic emotional regions were defined during learning as depicted in figure 2 [17]. The first region involves negative emotions like frustration, boredom or anger (negative

region I and II) and should be avoided. The second region is the target emotional region specified by a slight positive valence and neutral arousal. This region provides a maximum of efficiency and productivity in learning [17]. In our study, we focused on the proportion of positive emotions in the target region. We weighted then the number of HR and GSR recordings corresponding to this region by the total number of recordings.

3.3 Experimental Protocol

Upon arrival at the laboratory, participants were briefed about the procedure and consent was obtained. They were then randomly assigned either to the experimental condition or to the control condition. The former took place with self-esteem conditioning subliminal stimuli and the latter with no subliminal stimuli. Baselines for physiological signals were recorded during which participants were instructed to relax. The logic materials were then displayed with the instructions, warm-up examples and questions related to each of the three modules as described earlier. Finally, participants were asked to complete the IPT self-esteem scale.

3.4 Participants

39 participants ranged in age from 19 to 47 years ($M = 27.34$, $SD = 6.78$) took part to our study. They received 10 CAD compensation for their participation. They were assigned either to the experimental condition or to the control condition. Repartition of participants is given in Table 1.

Table 1. Repartition of participants

	Males	Females
Experimental condition	13	7
Control condition	11	8

4 Results and Discussion

Results are presented in four sections. The first section presents self-esteem measure results. The second section deals with learner performance. The third section analyzes learner affective states. Finally, the fourth section describes the overall influence of priming conditions and affective measures on learner performance.

Self-esteem. Learner self-esteem was measured in terms of IPT effect by using the I-algorithm [19]. Mean rating of all non-initial letters is subtracted from each letter rating. Normative letter baselines are then computed by averaging the ipsatized letter ratings for individuals whose initials do not include the letter. The difference score is finally computed between the ipsatized initial ratings and the respective ipsatized baselines [19]. Means and standard deviation of IPT scores are listed in Table 2.

Table 2. Means and standard deviations of IPT self-esteem measure

	M	SD
Experimental condition	1.68	.94
Control condition	1.08	.99

It is shown that the IPT effect was more pronounced for participants in the conditioned self-esteem group (experimental condition) compared to participants in the control condition indicating higher self-esteem. This difference was statistically reliable, $F(1, 37) = 4.84, p < .05$. Hence, results confirm that our method produced the expected main effect on learners' self-esteem.

Learning Performance. To measure learner performance we considered marks obtained in the logic questionnaire. Figure 3 presents the average marks in each module of the quiz. It is shown that participants in the experimental group have had better marks in the 3 categories of questions. Besides, questionnaire final marks were significantly higher in the experimental condition ($M = 33.4, SD = 12.36$) compared to those in the control condition ($M = 25.5, SD = 9.87$), $F(1, 37) = 4.37, p < .05$.

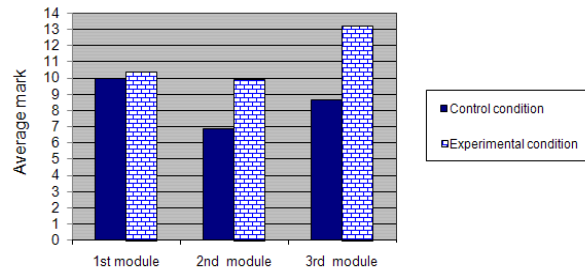


Fig. 3. Average marks per module

In another prospect, we analyzed the number of no-answers in both groups of participants. A main effect was found: $F(1, 37) = 7.45, p < .05$. The number of no-answers was significantly lower in the experimental condition ($M = .95, SD = .83$) compared to the control condition ($M = 2.11, SD = 1.91$).

To sum up, a clear evidence of the positive effect of the priming strategy on learners' marks in the questionnaire was found. This was a priori explained by a higher risk taking in the conditioned self-esteem group of participants since that an incorrect answer was worth -1 point and a no-answer worth 0 point in the final mark.

Learner affect. In our next investigation, we compared mental and emotional activities between participants of the experimental condition and participants of the control condition. For the mental activity, we considered participants' mental concentration while answering to the questionnaire tasks. Figure 4 sketches out the variation of the mean percentage of delta_low_theta in each question of the quiz with regards to the baseline for two participants. The first participant was primed with subliminal self-esteem conditioning primes, and the second one was not projected with primes: mean percentage of delta_low_theta band in each question was

subtracted from the baseline value. It is shown that in 12 questions over 15, the first participant has had a higher increase in delta_low_theta activity than the second one regarding to their respective baselines.

An overall effect was found: subliminally primed participants reported a higher increase in the percentage of delta_low_theta band with regards to the baseline ($M = 3.59$, $SD = 16.81$), compared to not primed participants ($M = 1.14$, $SD = 10.14$). The effect was statistically reliable ($F(1, 583) = 4.3$, $p < .05$).

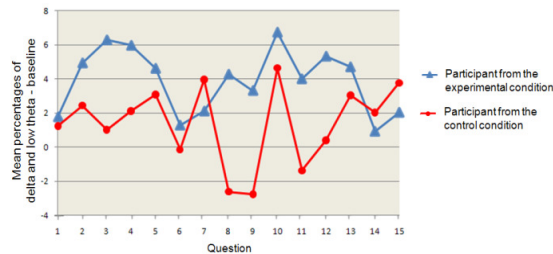


Fig. 4. Variation of mean percentage of delta_low_theta

Hence, it was found that participants with conditioned self-esteem yielded higher delta_low_theta activity and thus higher concentration level during tasks [13].

To analyze participants' emotional states, we look at the positive target emotion proportions over each question of the quiz. A significant main effect of priming conditions was found, $F(1, 583) = 6.03$, $p < .05$. Participants of the experimental group reported higher target emotion proportions ($M = 48.15$, $SD = 37.32$) than participants in the control condition ($M = 40.36$, $SD = 34.02$). This reflects that conditioned self-esteem participants were more frequently in the positive emotional target region.

Regression analysis. Our last investigation dealt with the overall impact of the learners' recorded affective data and self-esteem conditioning on learning performance. That is can we predict the learner results in the questionnaire on the basis of his priming condition, mental concentration, and emotional state. A multiple regression analysis was conducted to measure the influence of each of these parameters. The dependent variable used was participants' marks on each question of the quiz. Three predictors were used in the analysis: (1) priming conditions (coded +1 for the experimental condition and -1 for the control condition), (2) variation of the mean percentage of delta_low_theta with regards to baseline and (3) mean proportion in the emotional target region.

The overall model was significant ($F(3, 581) = 6.91$, $p < .01$, $R^2 = .34$). Conditional main effect analyzes revealed the expected positive effect of priming conditions ($\beta = .95$, $p < .05$). A main effect was also found for the variation of percentage of delta_low_theta ($\beta = .13$, $p < .05$) and for the proportion in the emotional target region ($\beta = .93$, $p < .05$). From this result, we can statistically deduce that learners' results in the questionnaire were positively influenced by the self-esteem priming condition, high mental concentration and more frequent emotions in the target region characterised by a slight positive valence and neutral arousal.

5 Conclusion

In this paper, we have proposed to use the self-esteem component within learning process. More precisely, our objective was to enhance learner implicit self-esteem while interacting with a tutoring system. Our approach is based on a subliminal, non-consciously perceived, self-esteem conditioning method.

Our experimental study has shown that this method enhanced participants' implicit self-esteem on one hand, and learning performance in terms of marks obtained in the logic questionnaire, on the other hand. Besides, priming conditions elicited different mental and emotional reactions: conditioned self-esteem participants showed higher mental concentration and higher proportions of positive emotions with regards to the target emotional region of Russel's circumplex model. Finally, we proposed to evaluate the contribution of each variable derived from learners' physiological signals and priming conditions for the prediction of learners' results in the questionnaire.

We believe that these findings can yield interesting implications in intelligent tutoring systems. Nevertheless, many ethical concerns should be established before applying subliminal strategies in applied settings [15]. Our future work is directed towards studying the impact of the self-esteem conditioning approach on a broader set of learner physiological features such as motivation, and mental workload. We also plan to conduct deeper analysis on correlations between learner self-esteem level, emotions and mental state within more complex learning situations.

In another perspective, we intend to model learners' level of self-esteem from their personal characteristics and physiological activities in order to extend the learner's module within an intelligent tutoring system.

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