

Implicit Strategies for Intelligent Tutoring Systems

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Abstract. Nowadays several researches in Intelligent Tutoring Systems are oriented toward developing emotionally sensitive tutors. These tutors use different instructional strategies addressing both learners' cognitive and affective dimensions and rely, for most of them, on explicit strategies and direct interventions. In this paper we propose a new approach to augment these tutors with new implicit strategies relying on indirect interventions. We show the feasibility of our approach through two experimental studies using a subliminal priming technique. We demonstrate that both learners' cognitive and affective states can be conditioned indirectly and show that these strategies produce a positive impact on students' interaction experience and enhance learning.

Keywords: Implicit tutoring strategies, Unconscious processes, Subliminal priming, Affect, Cognition.

1 Introduction

The development of Intelligent Tutoring Systems (ITS) began in the 1970's in an attempt to enhance computer based instruction with artificial intelligence methods to provide a highly individualized teaching and feedback tailored to the needs of the learner. Their aim is to support learning by simulating human tutors' pedagogical skills and domain expertise and produce the same kind of learning and flexibility that might occur between teachers and students [1]. In the recent years, the dynamics of learning has been shifting steadily from purely cognitive aspects of teaching to affect-sensitive tutors. This change can mainly be explained by recent advances in cognitive science, artificial intelligence, and neuroscience showing that the brain mechanisms associated to emotions are not only related to cognitive processes, such as reasoning, but also solicited in perception, problem solving and decision making [2].

Indeed, various research areas including education, psychology, computational linguistics, and artificial intelligence have shown a growing interest in the close links between affect and learning [3-8] as emotions have an impact on attention, motivation, memorization, and information processing [9]. This fact is especially true in the ITS community where several researchers have developed emotionally intelligent tutors able to respond to students on a personal level, identifying their actual emotional states and adapting their teaching accordingly [3, 8, 10-12].

However these tutors still need to be enhanced to track changes in learners' mental states especially when cognitive tasks such as reasoning and decision making occur. Furthermore, most of these tutors rely on explicit¹ strategies and direct interventions when interacting with the learner. These strategies can be in some cases excessive, inappropriate, or intrusive to the dynamics of the learning session. They can also be approximate or target basically, superficial aspects of the interaction.

In this research we propose to enhance these strategies with implicit interventions that can be more subtle and have the ability to target deeper affective and cognitive aspects involved in the learning process. Our work is based on evidence from the neuropsychology that suggests that cognition and affect involve some forms of implicit or unconscious processing that can be implicitly solicited [13]. In this paper we propose an approach to augment these tutors with new implicit strategies relying on indirect interventions in a problem solving environment in order to enhance cognitive abilities such as reasoning and condition affective states such as self-esteem while learning takes place.

2 Previous work

A variety of explicit strategies have been developed and evaluated within different learning environments providing both cognitive and affective feedback.

Some researches are oriented toward psychological theories to induce positive emotions in students [14], while others mostly use punctual, task-related and less intrusive interventions that can be directly integrated in the dynamics of the learning session. These strategies rely on a variety of task-based support policies to respond to particular students' affective states. This can be in the form of examples or definitions to help the students understand specific concepts. For example in [6], if the tutor realizes that the learner is bored, he engages him in a variety of stimulating tasks, a particular challenge or a game. If frustration is detected, the tutor provides statements or corrects certain information that the learner might have poorly assimilated. In [3], the ITS reacts differently to frustrated learners. It provides an indication or other similar problems to help the learner. In case of boredom, and depending on the situation, the tutor proposes an easier problem to motivate the learner in solving it, or increases the level of difficulty if the problem is too easy. The corrective mechanisms involved here are all direct and explicit and are applied a posteriori, that is once the student makes a mistake or reacts negatively to a situation.

Other approaches integrate more sophisticated companion technologies using life-like characters allowing real-time affective interactions between virtual pedagogical agents and learners [3, 4, 11, 12]. These agents may have a human appearance dialoguing with learners, communicating various messages of encouragement or congratulation; appearing to care about a learner's progress. Some agents can work with

¹ We define an explicit strategy as a tutoring intervention that occurs with a person's sensory or conscious perception. By contrast, an implicit strategy is an intervention that cannot be consciously perceived or reported by the learner. This implies that this intervention occurs without a learner's awareness and hence that does not interrupt the dynamics of the learning session.

the students on the same task, as study partners [8] and exchange on the problem they are solving by either offering advice and encouragement or helping them in coping with negative emotions (such as frustration, boredom, or fatigue). These companions can also adopt an empathetic response [3, 11, 12]. For instance in [12] an agent intervenes looking concerned when users are asked stressing interview questions leading to a drop in stress levels as measured by skin conductance. Although some of these tutors use physiological sensors to monitor students' affect, none uses brain data to monitor mental states and adjusts learning to cerebral changes that can occur in learners' cognitive reasoning processes. In another study [10], it is shown that empathetic responses of pedagogical learning companions improve learners' interest and self-efficacy but not learning outcomes. These agents can even simulate the behavior of the learner by adopting his expressions and actions [3, 4, 11, 12]. For example, Burleson [4] uses an agent that mimics the facial expressions and movements of the learner. It may for example, smile if it sees the learner smiling.

However, the aforementioned strategies only target aspects related to the direct interaction between the learner and the tutor. These strategies do not address the unconscious mechanisms underlying important cognitive and affective processing related to learning. The goal of this research is to augment, not replace, current learning strategies with implicit interventions. We believe that the complimentary nature of these new strategies can endow the current tutors with the ability to investigate, and hopefully enhance, the unconscious processes involved in emotional processing, reasoning and decision making. The following section will explain in more details these proposed strategies as well as present results from conducted studies.

3 Implicit strategies for Intelligent Tutoring Systems

As discussed in the previous section, current ITS rely on explicit strategies that address only measured variables involved in the direct interaction between the tutor and the learner. In this paper we aim to enhance these strategies with implicit interventions that address more subtle unconscious processes involved in both learners' affect and cognition. The basis of this work relies on previous findings from neuropsychological studies suggesting the possibility of nonconscious perception (or perception without awareness), because of the existence of a boundary threshold between conscious and unconscious perception [15]. A stimulus below this threshold of awareness (called subliminal stimulus) cannot be consciously perceived but can yield emotional and cognitive reactions [15, 16]. This phenomenon is known as subliminal perception: it unconsciously solicits affective and cognitive mechanisms in the human brain [13].

Masked priming is one of the most widely used technique for subliminal perception [15]. It consists in projecting for a very short time, a subliminal stimulus or prime such as a word or a valenced image preceded and/or followed by the projection of a mask for a particular time. This mask is usually in the form of a set of symbols that have nothing to do with the prime in order to elude its conscious detection [15]. In this research, our goal is to enhance existing tutoring strategies with masked priming

techniques. We will present two different priming approaches, namely affective priming and cognitive priming applied in problem solving environments.

3.1 Affective priming

Affective priming is a masked priming technique that consists in exposing participants to affective stimuli that can only be unconsciously perceived in order to implicitly elicit emotional reactions. These stimuli can be in the form of images or words charged with valenced semantics (e.g. smiling faces or positively connoted words). This technique is based on work in implicit memory [17] and automatic and unconscious processes related to stereotypes and attitudes [18]. This body of work suggests that implicit and unconscious elements are found in several psychological manifestations among which, emotional regulation. This technique has been studied in areas such as social behavior, advertising and stereotypes (see [16] for a review). Furthermore, these studies show that emotions are more likely influenced by these unconsciously perceived stimuli than by consciously perceived stimuli.

Conducted study. We used an affective priming technique in order to implicitly condition learners' affect within a logical problem solving environment. The aim of the study was to enhance learners' implicit self-esteem while they follow a learning session about logics. The goal is to teach learners how to infer a logical rule from a series of data in order to find the missing element of a sequence. The session starts with a tutorial giving instructions and examples to get learners accustomed with the user interface and types of questions, then a series of logical exercises are given.

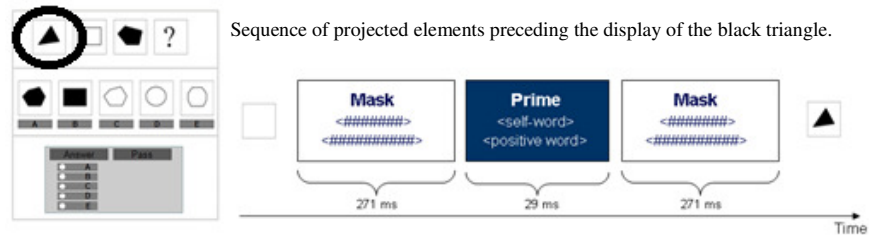


Fig. 1. Affective priming during problem solving

Three modules are taught, each one 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 (see [19] for more details). Learners are asked to respond as quickly and efficiently as possible to each of the 15 questions of the quiz. They are informed that they can either respond or pass the question and that a correct answer = 4 points, an incorrect answer = -1, and a no-answer = 0. Questionnaire materials (shapes, numbers and letters) are presented sequentially on the screen and subliminal primes are projected just before the materials.

In this study, a particular form of masked priming was used, namely the Evaluative Conditioning (EC) technique [20]. This method consists in subliminally projecting

self-referential words (conditioned stimulus) such as “I” or the first name of the learner, paired with positively valenced words (unconditioned stimulus) such as “efficient”, “success” or “smart”. The idea behind EC is that this conditioning implicitly influences the semantic structure of associations (between words) in memory and hence, the automatic affective reactions resulting from this pairing [20]. Fig. 1 gives an overview of how the masked priming took place. Each prime, consisting of a self-referential word and a positive word, is projected for 29 ms and is preceded and followed by a 271 ms mask composed of sharp (#) symbols.

A total of 39 participants with a mean age of 27.31 ± 6.87 years, were recruited for the experiment. Participation was compensated with 10 dollars. They were randomly assigned either to the experimental condition (N = 20, 13 males) or to the control condition, without priming (N = 19, 11 males). Participants’ self-esteem was assessed with the Initial Preference Task (IPT), a widely used technique for assessing implicit self-esteem, using the Ipsatized double-correction scoring algorithm (see [21] for more details).

Two sensors were used to measure participants’ emotional reactions, namely galvanic skin response, known to be correlated to emotional arousal (low to high) and blood volume pulse from which heart rate, known to be correlated to valence (positive to negative), was extracted [22]. The proportions of emotions characterized with a positive valence and a neutral arousal (Target emotion proportions) were assessed with regards to the baseline values, to measure participants’ positive emotional activations using a two dimensional model of affect [23]. These specific emotions are assumed to provide a maximum of efficiency and productivity in learning [24].

Table 1. Experimental results of the affective priming study

	Experimental condition		Control condition	
	M	SD	M	SD
Self-esteem	1.68	0.94	1.08	0.99
Target emotion proportions	48.15	37.32	40.36	34.02
Final score	33.4	12.36	25.5	9.87
Number of passed answers	0.95	0.83	2.11	1.91

Further variables were recorded to measure learners’ performance, namely, the final score in the test and the number of passed answers. Results are summarized in Table 1. A significant evidence for the conditioning effect on self-esteem was found. Primed participants showed significantly higher self-esteem than the control group, $F(1, 37) = 4.84$, $p < 0.05$ ($M = 1.68$ vs. 1.08). Besides, they showed significantly higher proportions of target emotions, $F(1, 583) = 6.03$, $p < 0.05$, in the logical quiz ($M = 48.15\%$) with regards to non primed participants ($M = 40.36\%$). The scores of the test were also better in the experimental group ($F(1, 37) = 4.37$, $p < 0.05$, $M = 33.4$ vs. 25.5), and unlike the control group, participants were taking more risks by answering more questions (lower number of passed answers, $F(1, 37) = 7.45$, $p < 0.05$, $M = 0.95$ vs. 2.11) even if they were not completely sure of their answers.

3.2 Cognitive priming

Like affective priming, cognitive priming is a masked priming technique, but with a different objective; the stimulus used (an answer or a hint about a question for example) is aimed toward positively enhancing specific cognitive processes such as reasoning or decision making toward the goal of implicitly enhancing knowledge acquisition. This technique is based on numerous findings in neuroscience providing evidence from the brain wave activity using electro-encephalography (EEG), demonstrating that unconsciously perceived stimuli can reach orthographic, lexical and motor levels of representations (see [25] for more details).

Conducted study. In this second study, we used a cognitive priming technique in order to implicitly enhance learners' reasoning abilities within a problem solving environment. The aim of the study was to use cognitive priming to specifically enhance the analogical reasoning abilities of students while learning how to construct an odd magic square of any order with the use of neither a calculator nor one mental arithmetic operation. A magic square of order n is a square containing n^2 distinct integers disposed in a way such as all the n numbers contained in all rows, columns or diagonals sum to the same constant (leftmost part of Fig. 2).

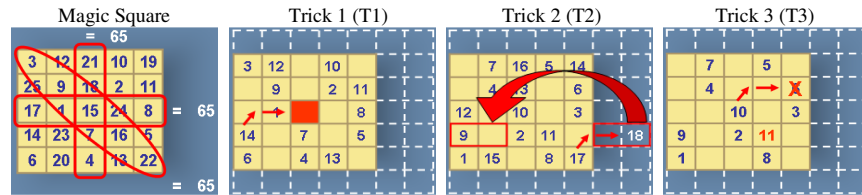


Fig. 2. Magic square and the three tricks taught

To construct such a magic square, three tricks are required (Fig. 2). These tricks are cumulative and thus the difficulty increases with each trick. The solution to the three tricks was not presented. Instead, the learners had to infer their own solutions, correctly figure out the different algorithm used in each trick and answer a series of 13 questions (see [26] for more details). Furthermore, learners were instructed to make the fewest amounts of mistakes possible whilst taking the shortest amount of time. Then, learners reported how they figured out each trick by choosing between the following: "I deduced the trick by intuition, logic, a little of both" (Trick answer type variable). Learners also reported how they answered each question by choosing between the following: "I answered the question by guessing the answer, by intuition or by logical deduction" (Question answer type variable). Learners' brain activity (using EEG) was recorded to investigate changes in mental activity during reasoning.

In this study, two experimental conditions with different types of primes were considered namely Answer_cues and Miscues. The former condition intended to enable learners to reason faster while deducing the tricks. The primes are in the form of arrows pointing at the answer to each trick as displayed in Fig.2. The Miscues condition

is intended to mislead the learner using primes (arrows) that point to the wrong square on the screen. The idea of the study was to assess the effect of each type of prime on reasoning. In both conditions, primes (Answer_cues and Miscues) were displayed in each trick throughout the study. Each prime is projected for 33 ms and is followed and preceded by a mask of 275 ms consisting of random geometric figures.

A total of 43 participants with a mean age of 27 ± 3.5 years, were recruited for the experiment and were compensated with 10 dollars; they were randomly assigned either to the Answer_cues condition (N = 14, 7 males), to the Miscues condition (N = 14, 6 males) or to the Control condition, without priming (N = 15, 7 males).

We were interested in examining results related to performance (number of mistakes) with regards to the way learning occurred (Trick answer type), the way learners answered questions (Question answer type) and the group (Answer_cues, Miscues, Control). Significant effects were only found for the variables Trick answer type* group with regards to the number of mistakes with the following combinations: Logic*Answer_cues ($p = 0.002$, $\alpha = 0.05$, $\chi^2 = 16.949$), A little of both*Answer_cues ($p = 0.048$, $\alpha = 0.05$, $\chi^2 = 9.117$). Results seem to indicate that only Answer_cues, and not miscues, do significantly influence logical reasoning and decision making when learning a trick logically.

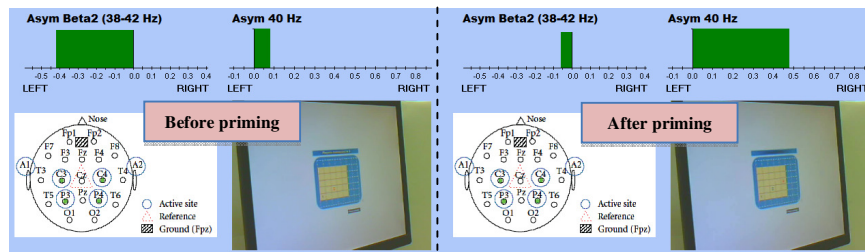


Fig. 3. Recording of cerebral changes following cognitive priming in intuitive reasoning

From the EEG data we were interested in investigating changes in two metrics that have previously been reported as relevant indicators of insightful problem solving (40Hz right asymmetry) [27] and complex arithmetic processing (Beta2 left asymmetry) [28]. We observed that the asymmetry values for the 40Hz ($p = 0.003$, $\alpha = 0.05$) and Beta2 ($p = 0.04$, $\alpha = 0.05$) in the Answer_cues group are significantly different than the Miscues group for the third and most difficult trick. Participants of the Answer_cues group seem to shift their attention from a complex arithmetic process (Beta2 left asymmetry decrease) toward an “insightful” problem solving strategy (40Hz right asymmetry increase), thus involving the right side of the brain, known to be an important actor in insightful problem solving. Fig. 3 depicts one such example recorded during learning where we see a female learner reporting learning the third trick (T3) by intuition. We see the decrease in Beta2 in the left brain and the increase in 40Hz in the right brain after priming, illustrating that a combination of these two metrics could indeed be an interesting indicator of a change in the reasoning strategy from complex arithmetics to an insightful reasoning during problem solving.

4 Discussion

The two presented studies have shown that learners' self-esteem and abilities to reason in a problem solving environment can be augmented through the use of affective and cognitive priming. The two experiments rely on a masked priming technique consisting in projecting stimuli below the threshold of conscious awareness (positively charged words paired with self-referential words and hints about the task).²

The affective and cognitive dimensions of these implicit interventions have been investigated and results have shown that electro-physiological sensors can provide current tutors with relevant information regarding the positive impact of the proposed approach in terms of learners' emotional and mental reactions. In light of those results, we believe that a hybrid ITS, one using both explicit and implicit strategies, can greatly enhance the interaction with a learner, enabling him to optimize his learning experience with both direct and indirect aspects. The proposed approach for integrating our implicit tutor is illustrated below.

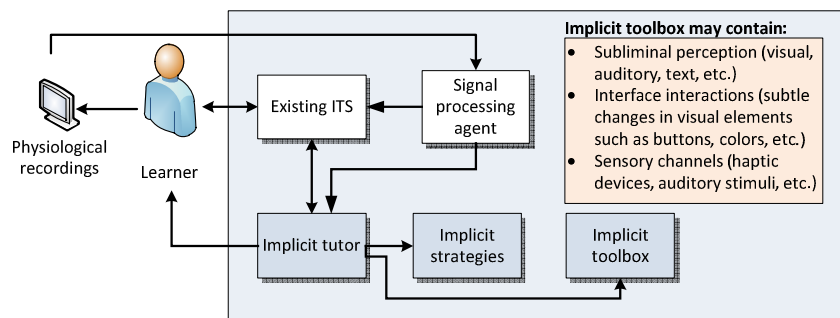


Fig. 4. Proposed approach

The implicit tutor is continuously communicating with the explicit tutor in search of the best strategy to apply in a given situation. To achieve this objective, the implicit tutor can choose one or multiple implicit strategies (cognitive and/or affective priming) as well as a *kind* of stimulus to project. The implicit toolbox is essentially a guide of all existing stimuli that are applicable for a situation. In this paper, we have presented two studies employing different subliminal stimuli (visual and textual). However, we believe that two issues need to be addressed, before this integration could take place in a real learning environment. First, the implicit strategies have to be tested in complex, real-life, lessons where deeper learning may take place and compare results. Second, ethical issues of deploying these strategies should also be explored. It would be interesting for example to reproduce these studies while informing the learners of *what* will they get but not *how*. In other words, explain that the system is built to provide help in a subtle way without revealing the kind of stimuli that will be used from the toolbox and crosscheck results.

² In both experiments, none of the participants has reported seeing the primes during the tasks.

5 Conclusion

This paper discusses a new approach to enhance ITS with implicit tutoring strategies targeting subtle indirect aspects in the interaction between the tutor and the learner. These strategies are based on unconsciously perceived interventions that address the automatic mechanisms associated to learners' affective and cognitive processing inherent to learning using the subliminal perception. We demonstrated our approach through two experimental studies showing two different applications of the masked priming technique, namely affective priming and cognitive priming. We showed that both learners' cognitive and affective states can be conditioned implicitly and that these strategies can produce a positive impact on students' interaction experience and enhance learning. The first study showed that affective priming had a positive impact on learners' outcomes, self-esteem, and emotional reactions. The second study showed that cognitive priming enhanced learners' reasoning abilities and EEG data demonstrated that cognitive abilities such as analogical reasoning can potentially be monitored, assessed and positively influenced under priming conditions.

In our future work, we are interested in developing a tutor that will integrate both implicit and explicit interventions. This tutor will select appropriate strategies according to learners' profile, and real time data from learners' progress and emotional and mental reactions.

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References

1. Seidel, R.J. and O. Park, An Historical Perspective and a Model for Evaluation of Intelligent Tutoring Systems. *Journal of Educational Computing Research*, 1994. 10(2): p. 103-128
2. Phelps, E.A., Emotion and cognition : Insights from Studies of the Human Amygdala. *Annual Review Psychology*, 2006. 57: p. 27-53.
3. Arroyo, I., K. Ferguson, J. Johns, T. Dragon, H. Meheranian, D. Fisher, A. Barto, S. Mahadevan and B.P. Woolf, Repairing Disengagement With Non-Invasive Interventions, in *Artificial Intelligence in Education: Building Technology Rich Learning Contexts That Work*, 2007, IOS Press.
4. Bursleson, W., Affective learning companions: strategies for empathetic agents with real-time multimodal affective sensing to foster meta-cognitive approaches to learning, motivation, and perseverance, 2006, MIT PhD thesis.
5. Conati, C., Probabilistic Assessment of User's Emotions in Educational Games. *Applied Artificial Intelligence*, 2002. 16: p. 555-575.
6. D'Mello, S. and A. Graesser, Automatic detection of learner's affect from gross body language. *Applied Artificial Intelligence*, 2009. 23: p. 123-150.
7. Litman, D. and K. Forbes-Riley, Annotating student emotional states in spoken tutoring dialogues, in *SIGdial Workshop on Discourse and Dialogue*, 2004: Boston, USA. p. 144-153.

8. Woolf, B., W. Bursleson, I. Arroyo, T. Dragon, D. Cooper and R. Picard, Affect aware tutors : recognising and responding to student affect. *Int. J. Learn. Technol.*, 2009. 4(3/4): p. 129-164.
9. Pekrun, R., The Impact of Emotions on Learning and Achievement: Towards a Theory of Cognitive/Motivational Mediators. *Applied Psychology*, 1992. 41(4): p. 359-376.
10. Kim, Y., Empathetic virtual peers enhanced learner interest and self-efficacy, in *Workshop on Motivation and Affect in Educational Software*, in conjunction with the 12th International Conference on Artificial Intelligence in Education, 2005.
11. McQuiggan, S.W., S. Lee and J.C. Lester, Early Prediction of Student Frustration, in *Proceedings of the 2nd international conference on Affective Computing and Intelligent Interaction*, 2007, Springer-Verlag: Lisbon, Portugal.
12. Prendinger, H. and M. Ishizuka, The empathic companion: A character-based interface that addresses users' affective states. *Applied Artificial Intelligence*, 2005. 19: p. 267-285.
13. Kouider, S., S. Dehaene, A. Jobert and D. Le Bihan, Cerebral Bases of Subliminal and Supraliminal Priming during Reading. *Cereb. Cortex*, 2007. 17(9): p. 2019-2029.
14. Mayer, J.D., J. Allen and K. Beaugard, Mood inductions for four specific moods: A procedure employing guided imagery vignettes with music. *Journal of Mental Imagery*, 1995. 19: p. 133-150.
15. Del Cul, A., S. Baillet and S. Dehaene, Brain dynamics underlying the nonlinear threshold for access to consciousness. *Public Library of Science, Biology*, 2007. 5(10): p. 2408-2423.
16. Hassin, R., J. Uleman and J. Bargh, *The new unconscious*. 2005, Oxford, UK: Oxford University Press.
17. Tulving, E. and D. Schacter, Priming and human memory systems. *Science*, 1990. 247(4940): p. 301-306.
18. Bargh, J.A., S. Chaiken, R. Govender and F. Pratto, The generality of the automatic attitude activation effect. *Journal of Personality and Social Psychology*, 1992. 62(6): p. 893-912.
19. Jraidi, I. and C. Frasson, Subliminally Enhancing Self-Esteem: Impact on Learner Performance and Affective State, in: *the 10th International Conference on Intelligent Tutoring Systems*, 2010: Pittsburgh, Pennsylvania, USA.
20. Grumm, M., S. Nestler and G.v. Collani, Changing explicit and implicit attitudes: The case of self-esteem. *Journal of Experimental Social Psychology*, 2009. 45(2): p. 327-335.
21. LeBel, E.P. and B. Gawronski, How to find what's in a name: Scrutinizing the optimality of five scoring algorithms for the name-letter task. *European Journal of Personality*, 2009. 23: p. 85-106.
22. Lang, P.J., The emotion probe: Studies of motivation and attention. *Am. Psy.*, 1995. 50(5): p. 372-385.
23. Russell, J., A circumplex model of affect. *JPSP*, 1980. 39: p. 1161-1178.
24. Kaiser, R., Prototypical development of an affective component for an e-learning system. Master Thesis, Department of Computer Science, University of Rostock, Germany, 2006.
25. Gaillard, R., L. Naccache, P. Pinel, S. Clémenceau, E. Volle, D. Hasboun, S. Dupont, M. Baulac, S. Dehaene, C. Adam and L. Cohen, Direct Intracranial, fMRI, and Lesion Evidence for the Causal Role of Left Inferotemporal Cortex in Reading. *Neuron*, 2006. 50: p. 191-204.
26. Chalfoun, P. and C. Frasson, Subliminal cues while teaching: HCI technique for enhanced learning. *Advances in Human Computer Interaction : Special Issue on Subliminal Communication in Human-Computer Interaction*, 2011(1).
27. Sandkühler, S. and J. Bhattacharya, Deconstructing insight: EEG correlates of Insightful Problem Solving. *PLOS One*, 2008. 3(1).
28. Hyungkyu, K., C. Jangsik and L. Eunjung, EEG Asymmetry Analysis of the Left and Right Brain Activities During Simple versus Complex Arithmetic Learning. *Journal of Neurotherapy*, 2009. 13.