Helsinki, Finland

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To whom it may concern,

The workshop on Tools and Technologies for Emotion Awareness in Computer-Mediated Collaboration and Learning has relevance to my prior work in the EU-funded TARGET project. This project involved both tool development for emotion awareness and basic research on learning, in virtual Technology Enhanced Learning environments. Below I give a short description of the project and relevant experiments.

Background. The Transformative, Adaptive, Responsive and enGaging EnvironmenT (TARGET) project aims to empower users with fast and enjoyable ways to learn about, to master and improve upon, professional skills and insights in areas that are important to them, their peers, employers and society. To achieve its aim, TARGET has developed an innovative Technology Enhanced Learning (TEL) environment consisting of a learning process supported by the modular TARGET platform, targeting the domain of project management. The core component consists of a serious game combined with virtual world technology and emerging storytelling which provides individuals with complex situations in the form of engaging personalized game scenarios.

In the Knowledge Media Laboratory at Aalto University, our part of this project involved creating a component of the TARGET platform which would monitor the psychophysiological signals of the player and return an estimate of their state – the PsychoPhysiological Assessment Component (PPAC).

Methods. Initially we aimed to estimate the states of attention, pleasure, excitement, approach/withdrawal motivation and mental workload. Attention along with motivation required Electroencephalography (EEG) measurement; pleasure (positive and negative valence) was measured with facial Electromyography (fEMG); we used Electrocardiography (ECG) along with EEG to measure mental workload and we used Electrodermal activity (EDA) along with ECG to measure excitement or arousal.

This component was tested in two experiments. The first (*exp1*) used prototypical stimuli for the elicitation of the targeted emotions/mental states, such as the IAPS picture set to elicit arousal and valence, or visual search pictures to elicit levels of attention and mental workload. This data was used to train and test a set of Naive Bayes (NBC) and Random Forest (RFC) classifiers for each state. We used temporal features of the four signals as they have a better computational profile for real-time implementation. The second experiment (*exp2*) validated the classifiers using the TARGET game itself.

While building the player-state classifier was one important branch of our work, in this project we also studied the psychophysiological correlates of player learning. Based on a further two experiments we examined the psychophysiological signals of players, including fEMG, ECG, EDA and also respiration rate, in order to detect any patterns which would predict their learning. The first experiment was conducted before TARGET was developed and so used a proxy game (*exp3*); the second used the data from the PPAC validation mentioned above (*exp4*). Learning was assessed by pre- to post-play questionnaires to derive *gain* scores. These were then analysed as dependent variables in a Generalised Estimating Equations (GEE) model structure with mean psychophysiological variables as independent variables.

Results. With temporal features and feature selection, in *exp1* the NBC achieved ~93% accuracy based on 10-fold cross-validation for recognition of arousal from ECG and EDA. Accuracy for motivation was ~89% based on EEG features. Other states were less reliable: mental workload and valence both had maximum accuracy of 72%. In comparing the NBC and RFC algorithms, a mix of temporal and spectral features were used without feature selection to classify arousal states from mixed signal sources; RFC managed to achieve significantly better accuracy in all cases. The *exp2* validation testing was not so successful: training on the *exp1* stimuli and testing with game session data could only achieve ~42% accuracy for NBC or RFC, using holdout validation and no feature selection. Thus we see good potential for the developed component, but with the common problem of poor performance in ecologically valid scenarios.

In statistical learning tests, our GEE models showed a significant prediction for learning from Heart Rate Variability, across *exp3* and *exp4*. In the *exp3* proxy game the association was positive, B=0.003, SE=0.001, Wald Chi-Square (df=1)=4.11, $p < .05$. HRV is inversely related to mental workload, that is, *decreased mental workload during game playing was associated with better learning*. In *exp4* using the TARGET platform, the association was negative, B = -.59, SE = 0.16, Wald Chi-Square (df = 1) = 12.87, $p < .001$. This apparent contradiction is explicable under consideration of the types of gameplay involved: the proxy game, being a more polished and *game-like* experience, facilitated learning through cognitive efficiency as game skills were mastered and content learned by osmosis. The TARET platform, being a beta product, required more intense concentration. Thus it is the *type of interaction* between game and learning that really shape the efforts required by the learner, and perhaps ultimately, what kinds of people may benefit most from particular designs.

Conclusion. Within the field of TEL products, there is great need for increased certainty about the effects of particular pedagogical designs, both in the development process and in real-time. This project has contributed to the field on several fronts. Participation in the workshop will be an excellent opportunity to further disseminate the work, look for feedback and obtain fresh ideas on the state of the art in other labs.

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