DELEX: a DEep Learning Emotive eXperience

Investigating empathic HCI

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ABSTRACT

Recent advances in Machine Learning have unveiled interesting possibilities for real-time investigating about user characteristics and expressions like, but not limited to, age, sex, body posture, emotions and moods. These new opportunities lay the foundations for new HCI tools for interactive applications that adopt user emotions as a communication channel.

This paper presents an Emotion Controlled User Experience that changes according to user feelings and emotions analysed at runtime. Aiming at obtaining a preliminary evaluation of the proposed ecosystem, a controlled experiment has been performed in an engineering and software development company, where 60 people have been involved as volunteers. The subjective evaluation has been based on a standard questionnaire commonly adopted for measuring user perceived sense of immersion in Virtual Environments. The results of the controlled experiment encourage further investigations strengthen by the analysis of objective performance measurements and user physiological parameters.

CCS CONCEPTS

• **Human-centered computing → Interaction design**: *Empirical studies in interaction design*

• **Computing methodologies → Machine learning → Machine learning approaches:** *Neural Networks*

• **Computing methodologies → Artificial intelligence → Computer vision → Computer vision tasks:** *Vision for robotics, Biometrics*

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KEYWORDS

Deep Learning, Computer Vision, User Emotions, User Experience;

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INTRODUCTION

With the comprehension and diffusion of Deep Learning and the improvements of biometric features detection, understanding emotion has moved from a state-of-the-art specialized research activity to a daily task that may be executed also on the edge.

Humans are habituated at expressing emotions and on these they base many forms of implicit interaction with the others. It is not a case that human robot interaction is basing communication on forms of sentiment expressions. As an example, Pepper, the humanoid robot, adopts colours, shapes and movements for emotion expression and enriched interaction with users, inducing and transmitting human-like emotions.

In this work we present the DELEX approach, that goes in the opposite direction and aims at using machine learning to detect emotions in human users for establishing a communication channel that exploits a new form of implicit human computer interaction. At this aim, the proposed DELEX eco-system adopts the information about user emotions for controlling the dynamic behaviours of a software prototype (the VR application, proposed as immersive 3D environment) and of a smart lamp (the surrounding environment).

The DELEX approach can be applied to the user experience (UX) according to two opposite paradigms:

- *Emphasizing effect*: the dynamicity of the eco-system aims at increasing the intensity of user sensations during the experience and is suitable for gaming or infotainment experiences;
- *Mitigating effect*: the eco-systems reacts to user emotions with actions aiming at contrasting user

emotional state, that is proposed also for office applications and similar contexts.

In this paper we concentrate on the DELEX emphasizing effect by collecting user reactions when playing with a dynamic horror first person game simulation.
The application interacts with the surrounding environment by ideally extending the screen surface with light and color effects, accordingly produced by a smart lamp.

BACKGROUND

This section reports the state of art concerning emotion detection via user images, emotion control and user adaptive applications.
The concept of "basic" or "primary" emotions appears in a first-century Chinese encyclopedia, the Book of Rites, that identifies seven human feelings: joy, anger, sadness, fear, love, disliking, and liking.

Coming to the 20th century, Paul Ekman [8, 9] identified six basic emotions (anger, disgust, fear, happiness, sadness, and surprise) and Robert Plutchik eight, which he grouped into four pairs of polar opposites (joy-sadness, anger-fear, trust-distrust, surprise-anticipation) [18].

In [5], the authors adopt EEG waves and train a convolutional neural network (CNN) on the EEG signals of the DEAP [12] data set to classify the emotion of the subjects. In [14], Dahua et al. propose the adoption of the multimodal paradigm that introduces complementary information for emotion recognition and presents a decision level fusion framework for continuously detecting emotions by analysing the Electroencephalography (EEG) and facial expressions. As a future development of the current research, we also are thinking to improve the amount of information on users with physiological measures like EEG, heartbeat and others.

FER 2013 [10] is a well-known and largely adopted dataset of classified human emotions. It was firstly adopted for the facial expression recognition challenge of ICML 2013 Workshop. The dataset consists of grayscale images of faces with a resolution of 48x48 pixel. The faces are more or less centered and occupy about the same amount of space in each image. The dataset is composed of 28,709 facial expressions classified in to one of the seven categories: Anger, Disgust, Fear, Happiness, Sadness, Surprise and Neutral.
The FER+ data set is an evolution of the previous one in which some of the original images have been relabeled and other images have been completely removed.
The AffectNet [15] data set collects 287651 training images and 4000 validation images, manually annotated. Researchers [15, 24] evaluate their approaches on the validation set containing 500 images for each emotion of the following 8 classes: anger, contempt, disgust, fear, happiness, neutral, sadness and surprise.
After the success of the AlexNet deep neural network in the ImageNet Large Scale Visual Recognition Challenge (ILSVRC) [13], deep learning has been widely adopted in the computer vision research and, as affirmed by Georgescu et al., most of the recent works on facial expression recognition are based on deep learning [13].
In [25], Zhang et al. describe a face expression recognition method based on a CNN and on an image edge detection. In particular, the authors use the Keras framework [11] to build, train and execute the network. In this direction, also DELEX adopts a CNN for analyzing user images aiming at classifying the expressed emotions and will exploit advanced features of the ML framework for experimenting different DL architectures.

The well-known concept of Emotional Design in UX [19], aims at suggesting approaches for creating long-lasting and delightful UXs through emotions.

In the same direction described in [19], DELEX aims at increasing user involvement in the proposed experience by soliciting his/her emotions synchronizing action timing and surrounding lighting on detected user emotions.
In [20], Sroykham et al. experiment the observation of oxygen saturation, pulse rate, and quantitative electroencephalogram on five participants to the exposition of different color lights. The experiment shows that light has direct effect on visual and non-visual functions: sleep-awake cycle, autonomic nervous system, cognitive performance, mood, motor activity, memory, hormone production, cell cycle and biological clock. In particular, red and yellow colors in living environment seem stimulating the anger and confusion while white, blue, green, and black colors do not yield any different effects on user mood.
Abbas et al., has shown in [1] that there is a change in heart rate due to changes in colour and lighting conditions.
According to these founding, the color schema adopted in the gaming environment prosed for DELEX evaluation, is based on blue or green for neutral situations and red for the actions to be emphasized.
In [6], colors of user interface change according to the emotional states and mood state of users detected via keyboard and event interpretation.
Bermùdez et al., in [4], present the Emotional Labyrinth that consists of procedurally-generated 3D mazes whose shape and features are dynamically adapted to the emotional states of the user. The user explores the maze while visual and auditory features are procedurally generated according to four emotional states (Anger, Fear, Joy, Sadness) and changes in cardiorespiratory, electrodermal and electromyographic signals are being recorded.
As for the proposed DELEX approach, the goal of the application is to expose the participant to procedurally generated audio-visual VR content to induce specific user's emotional states.
Jumpscares (or Jump Scares) [16] are a technique often used in horror films and video games adopted to scare the audience by surprising them with an abrupt, but above all unexpected event, usually co-occurring with a scary sound and loud screaming.
DELEX approach, culminates with a jumpscare, but, supported by its Emotive back end, waits for the more opportune starting time for emphasizing its effect.

FNAF [17] stands for Five Nights at Freddy's, and is a successful example of indie horror game genre. The game inspired several clones and a rich community of passionate followers developing a big number of free 3D models and adventure settings. DELEX adopts FNAF animatronics for building its scary content. The choice of adopting animatronics as scary sources avoids rising race, gender or other ethical problems.

THE DELEX APPROACH

In this section, DELEX is presented in its effect emphasizing version. The ecosystem is made of a Virtual Reality (VR) application that immerses the user in a horror scenario and emphasizes with light, audio and camera focal variations, the sensations felt by its users. The flow of the horror simulation is not fixed, but it is controlled by the Emotive back end. We experimentally found that the less the user expects a scaring action, the stronger is the inducted sensation. Exploiting this observation, the Emotive BackEnd waits that the user is in the "Neutral" state for a while, before activating the final jumpscare.

General Architecture

The DELEX ecosystem is organized in two subcomponents:

- The Empathic application;
- The Emotion Backend.

The architecture of DELEX ecosystem is shown in Figure 1.

The Empathic Application hosts the visible part of the DELEX UX. At the aims of the presented experience and evaluation, it provides two analogous 3D simulations in the form of two horror first person adventures. The Video Streamer component controls the camera and sends user images to the Emotion BackEnd.

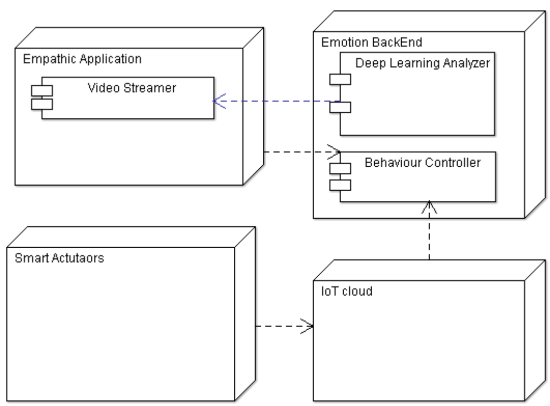

Figure 1: the deployment diagram of DELEX architecture

The Emotion BackEnd is responsible of the recognition of user emotions analyzing, by means of a deep CNN, the user images taken from the camera. At the moment, since we were searching for long sequences of user neutral expressions, the acquisition rate is not required to be high and we process only 3 frames per second. The Behavior Controller component organizes the timing of the experience proposed by the Empathic application and controls the surrounding environment by sending commands to the smart lamp. The Emotion Back End receives the images of the user and exposes the detected emotions to the dynamically customizable Empathic Application running on a TV monitor, that extends the gaming experience to the enlightening of the surrounding environment. The Emotion Backend is in communication with the Smart Actuators (the smart lamp) via their Restful back-end.

In Figure 2, the DELEX eco-systems, as seen by its users, is shown. A HD screen is playing the 3D application. The camera, anchored on the top of the screen, is pointed on the user and periodically streams the images of the user to the Deep Learning Analyzer of the Emotion BackEnd.

Figure 2: DELEX application and environment

The Emotion Back End

The gaming coordination is in charge to the Deep Learning Analyzer hosted on the Emotion BackEnd. The component analyses the user images captured by the webcam on the top of the gaming screen and feeds a deep CNN, trained on an augmented version of the FER dataset [10], obtained adding rotations, zoom, shifts, flip and shear to the original images. It is important to point out that the FER database is not fully balanced on its categories of expression, many samples are misclassified and many images are characterized by perturbating elements like copyright logos [3]. However, both respect to the adopted dataset and to the chosen neural architecture, it is important to point out that the proposed is just a preliminary solution and leaves room for improvements, that will be the object of future investigations. Even if for this experiment the Emotion BackEnd has been hosted on a regular laptop, DELEX simplified Deep Learning architecture will be delocalized on the edge and hosted on an embedded device, in the short future. This will enable the easy integration of emotion detection services in other smart applications.

The adopted net architecture is inspired to a simplified version of VGG [2] made of 4 convolutional blocks and 2 fully connected ones with a softmax activation layer. The 4 convolutional layers are similar and are composed of the Feature Map itself, the ReLU layer, a MaxPooling, for increasing generalization capabilities, and a dropout layer for reducing the possibility of training overfitting.

In the proposed experience, DELEX is exploited for its emphasizing role and needs only the knowledge about long periods of "neutral" use emotion. Different application of the proposed technique, will benefit of better Machine Learning accuracy. In these cases, the Deep Learning architecture adopted will be improved, changed and/or trained on a more general and balanced dataset respect to the one adopted for these first experimentations.

The emotional User Experience

To evaluate the user perceptions of the DELEX approach, two analogous 3D simulations have been developed:

1. The Hall (H);
2. The Alley (A).

The user controls are the classic arrow keys and the camera direction follows the mouse movement.
The Hall is an endless walk in a hallway. A walking sound accompanies the user that moves to the end of the corridor examining several disturbing objects along the path. The alley proposes the same gaming pattern of the Hall, but set in an urban alley.
In both the simulations, the cinematic trick of reducing the focal length of the shot increases the insecurity effect perceived by users. The colors and light pulse frequencies are used to further emphasize the user perceptions, both in the simulation and in the surrounding environment illuminated by a smart lamp.

Figure 3: the final jumpscare of The Alley

In the first part of both the experiences, the user walks forward in a narrow setting. DELEX approach is evaluated in two different scary moments that happen during user walk. The first one starts, after a fixed time, or on Emotion BackEnd trigger: the user sees and approaches the first scary object, the smart lamp turns on its stroboscopic mode at an increasing frequency and the user first person camera reduces the focal preventing him/her from visually approaching the target. After few seconds, the first stimulus to the user ends, but the camera objective remains in the wide-angle focal length.
In the case of DELEX approach, the Emotive BE controls the empathic application that, according to detected emotions, changes its behaviour and contents according also the intensity, the strobe frequency and the light color of the smart lamp.
After the command sent by the Emotion BackEnd (dynamically on user expressions, respect to the static classic approach), the second user Stimulus starts: the participant loses his/her control on the walk and, after a while, he/she is exposed to a jumpscare, a rapidly moving object associated to a howling noise, with the aim of inducing a strong emotion. Figure 3 depicts the climax of the jumpscare event of The Alley experience: the animatronic opens its face and exposes internal teeth.

EVALUATION

This Section provides the design and planning of the experiment, structured according to the guidelines described by Wohlin et al. in [22]. The goal of the experiment is to examine the perceived amplifying effects due to the adoption of DELEX in the context of a horror style first person videogame experience (emotion amplifying effect). Considering the context previously described, the research question may be formulated as follows:

Comparison with the static game flow: *"does DELEX outperform a traditional static horror game in terms of perceived emotions?"*.

Table 1: The experiment design

	Groups			
	A	**B**	**C**	**D**
Session 1	AD	A	HD	H
Session 2	H	HD	A	AD

Even if the two 3D virtual environments adopted for the evaluation are equivalent in terms of settings, objects, sounds and lighting, any possible effect due to differences is treated with the adopted fully balanced experiment design.
Accordingly, the participant grouping is detailed in Table 1: the controlled experiment involved every participant in both the simulations, playing the one with a fixed event timing and the other with the DELEX approach.
Before starting, the participants have been asked to answer to the preliminary questionnaire reported in Table 2 aiming at assessing their predisposition to involvement and their familiarity with 3D environments and videogames.
After every DELEX and NODELEX experience, user impressions have been collected using the Witmer and Singer questionnaire.

Table 2: The preliminary questionnaire

I am expert in 3D computer usage (3DG)
I am expert in the usage of videogames and Virtual Environments (3DG)
Often, I am involved in a game/simulation/virtual adventure and feel of being part of the game/simulation/virtual adventure rather than acting on controls or watching the screen (INV)
Often, I am deeply involved in doing something and lose track of time (INV)
I am scared by something happening on a TV show or in a movie (INV)
3DG = 3D environments and PC games knowledge, INV = tendency to become involved in virtual activities.

Witmer and Singer is one of the most used instruments to evaluate the UX in the virtual worlds in terms of immersion and perceived sense of presence. The Witmer and Singer questionnaire assesses with several questions, the four factors: Control Factor (CF), Realism Factor (RF), Sensory Factor (SF) and Distraction Factor (DF). The adopted presence questionnaire is inspired to the one described in [7] and consists of 31 questions measured on a seven-point Likert scale anchored with values 1=very low and 7=very high (not appropriate questions, like the ones formulated for haptic systems have not been included).

Table 3: The Witmer and Singer presence questionnaire

I was able to control events. (CF)
The environment was responsive to action I initiated (or performed). (CF)
Interaction with the environment was natural. (CF)
My senses were completely engaged. (SF)
The visual aspects of the environment involved me. (SF)
The auditory aspects of the environment involved me. (SF)
The movement control was natural. (CF)
I was aware of events occurring in the real world around me. (DF)
I was aware of the display and the control devices. (DF)
Sense of objects moving through space was compelling. (SF)
The information coming from my various senses was inconsistent or disconnected. (RF)
My experiences in the virtual environment seem consistent with real-world experiences (RF), (CF)
I was able to anticipate what would happen in response to the actions performed. (CF)
I was able to actively survey or search the environment using vision. (RF), (CF), (SF)
I could identify sounds well. (RF), (SF)
I could localize sounds well. (RF), (SF)
Sense of moving around inside the virtual environment was compelling. (SF)
I was able to closely examine objects. (SF)
I could examine objects from multiple viewpoints. (SF)
I could move or manipulate objects in the virtual environment. (CF)
I felt confused or disoriented at the beginning of breaks or at the end of the experimental session. (RF)
I was involved in the virtual environment experience. (INV)
The control mechanism was distracting. (DF)
I experienced delay between my actions and expected outcomes. (CF)
I quickly controlled the virtual environment experience. (CF)
At the end of the experience I felt proficient in moving and interacting with the virtual environment. (CF)
The visual display quality interfered or distracted me from performing assigned tasks or required activities. (DF)
The control devices interfered with the performance of assigned tasks or with other activities? (DF), (CF)
I could concentrate on the assigned tasks or required activities rather than on the controls. (DF)
I learned new techniques that enabled to improve performance? (CF)
I was involved in the experimental task to lost track of time. (INV)
CF = control factor, SF = sensory factor, DF = distraction factor, RF = realism factor, INV = involvement, HAPTC = haptic.

Table 4: The DELEX environment evaluation questionnaire

1	The DELEX environment is well organized.
2	The adopted object and control metaphors are intuitive.
3	Objects behavior is consistent with their nature and their actions.
4	Amount of information that is displayed on the screen is adequate.
5	Information on the screen is well organized.

Aiming at ensuring that wrong design or implementation of controls, content and other factors did not bias the result of the experiment, a final questionnaire on the proposed environment has been submitted to the participants.

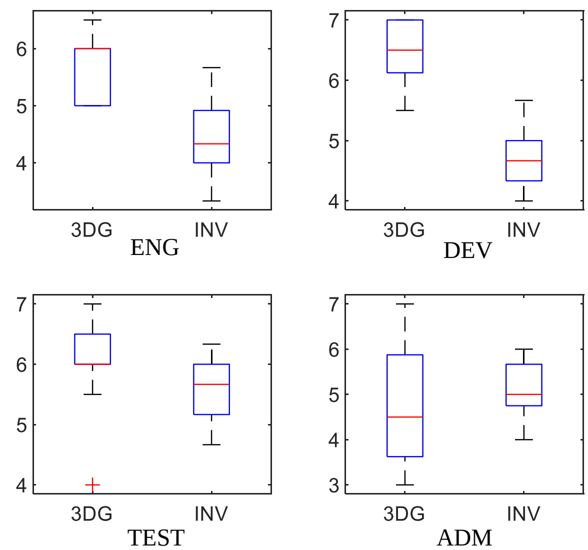

Figure 4: The results of preliminary questionnaire

Participants

The controlled experiment involved 60 Kineton employees (43 males and 17 females) with an average age of 27 years, different backgrounds respect to videogames and different areas of expertise (15 engineers [ENG], 15 developers [DEV], 15 testers [TEST] and 15 administration employees [ADM]).

Before starting the experiment, the subjects, organized in the four groups ENG, DEV, TEST and ADM, have filled the skill and character user questionnaire reported in Table 2;

Figure 4 depicts the subject answers to this preliminary questionnaire, aggregated in the four groups described above. Results are characterized in terms of computer and videogame skills (3DG) and in terms of personal predisposition for involvement (INV). It is possible to notice that the competencies well differentiate among the groups while the Involvement attitude is almost the same for all the groups.

Threats to validity

The experiment has been designed inspired by the guidelines provided in [22]. In particular, since the participant face two similar tests consecutively it is important to avoid learning effects between the two tasks.

At this aim, we adopted a fully balanced design that let only half of the participant to start with the DELEX treatment.

It is also important to point out that the only differences between the DELEX and NODELEX treatments are in the timing of gaming events. In both, the smart lamp acts coordinated with the game.

Concerning the reliability and validity of the questions, it is important to point out that the Presence questionnaire is a standard one [23], really used and well known, that has been largely discussed in literature. Arman and Slater in [21] confirm the choice of this questionnaire that is useful for measuring presence when all subjects experience the same type of environment. Indeed, we adopted this questionnaire because the proposed experience aims at comparing the same virtual environments just with or without the DELEX dynamicity.

Results of the Empirical Evaluation

In this Section we report the results of the proposed study, examining, in particular, the subjective evaluation related to the Witmer and Singer questionnaire.

The experiment provided three groups of results (all the 60 participants completed the experiment successfully) that were adopted for this preliminarily evaluation:

1. Pre-Experiment Questionnaire results concerning subjects' gender, age, videogame practice and emotivity (reported in Table 2).

2. Subjective impressions about DELEX collected via the Witmer and Singer presence questionnaire concerning factors like perceived control, distraction and involvement factors (Table 3).

3. User impressions on the DELEX ecosystem adopted as a final control mechanism supporting the validity of results (Table 4).

The idea that supports the choice of Witmer and Singer questionnaire is to use perceived Immersion and Involvement as a degree of how the DELEX approach is effective in proposing an attractive UX, by tuning the actions on detected user emotions. As described, both the experiences adopted for the evaluation have been designed to scare users and we expect to induce a deeper fear sensation thanks to the emotional control of DELEX. At the aim of the evaluation, we are not interested in the Realism Factor and Sensory Factor since the environments are almost the same and no difference may be really perceived. Interesting hints may be obtained by analysing Witmer and Singer questionnaire results that are reported in Figure 5 in terms of perceived Involvement, Control and Distraction factors.

The experiences controlled by the DELEX approach (average 5.558) have globally obtained higher scores in terms of perceived user Involvement respect to the classic ones (average 5.125). In this case, it is important to point out that the scores are more concentrated around the median in the case of DELEX respect to the classic application. We performed a paired T-test on Involvement questionnaire answers, aiming at better determining whether the difference between DELEX and NODELEX scores is significant. The test defined the null hypothesis that DELEX and NODELEX scores come from population with the same average values. The test result rejects the null hypothesis at the 1% significance level and with a p-value=0.31×10^{-6}, in favour of the alternate hypothesis that the DELEX scores with greater values.

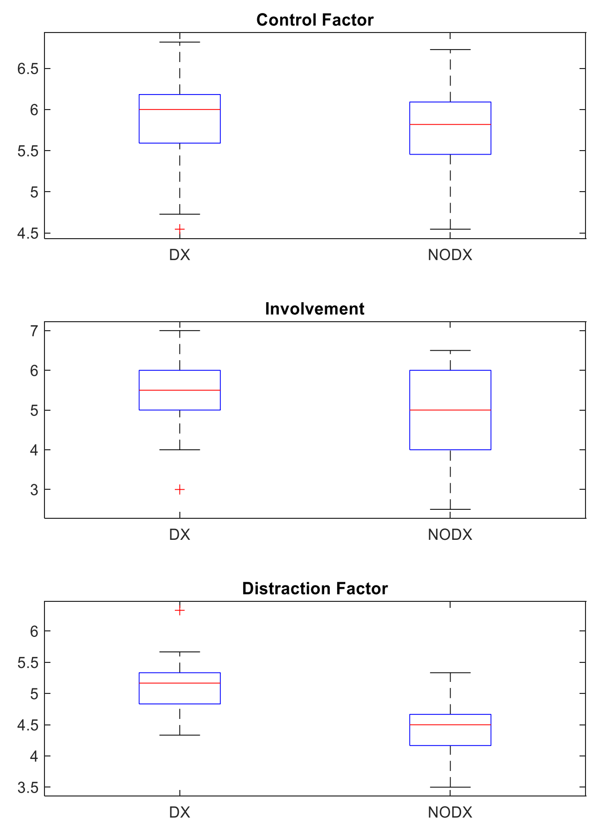

Figure 5: The results of Witmer and Singer questionnaire aggregated in the main survey factors.

Also, in the case of Control Factor, even if the interfaces exposed to users by the applications are almost the same, this has been evaluated better in the case of the DELEX approach.

What appears majorly interesting is the perceived distraction rates that, even if substantially do not change between the two modalities, have been felt lower during the DELEX experience by the users. It is important to point out, that, aiming at giving the same numerical meaning to the scores, the values of distraction factor have been reversed, and the higher the values, the lower distraction occasions have been perceived by users.

At the end of this preliminary evaluation, it appears evident that the DELEX approach results more attracting and involving users respect to the classic static horror videogame.

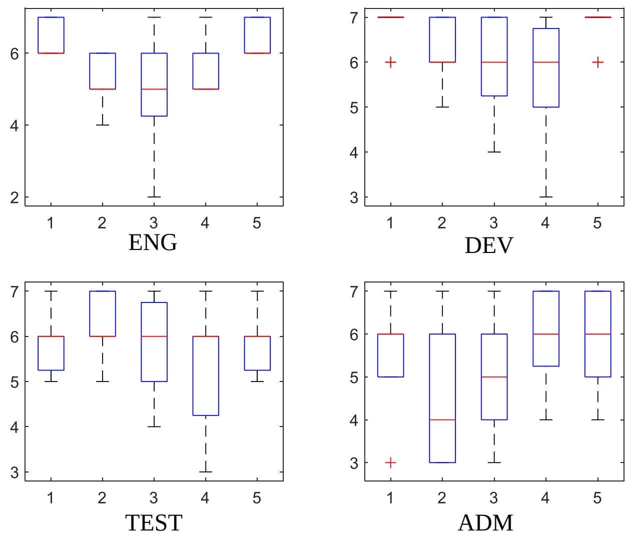

Figure 6: The results of DELEX environment evaluation questionnaire

Figure 6 reports the boxplots of the scores collected via the DELEX environment evaluation questionnaire reported in Table 4. All the scores are aggregated in the same user groups adopted for the preliminary questionnaire. As it is possible to see in Figure 6, the scores obtained by the DELEX environment in the final control questionnaire are high and it seems that no interface/control problem may have altered the evaluation results. DELEX scored minimum for question 2 "The adopted object and control metaphors were intuitive" that however is classified over the average by three of the four groups.

CONCLUSION

The controlled experiment results provide a first and quick positive answer to the research question: *"does DELEX outperform a traditional static horror game in terms of perceived emotions?"*. The results of the controlled experiment performed encourage further research activities that will go beyond the perceptions of DELEX users.

A new controlled experiment will be organized and will complement the actual results with objective indicators like performance scores, EEG tracks, heart rate and blood pressure measurements. Also, the application of DELEX will be extended to other scenarios soliciting and evaluating also its possible Mitigating effects.

The actual configuration of DELEX, in its emphasizing role, exploits fundamentally only the knowledge about long periods of a neutral use emotion. Mitigating capabilities of the proposed approach will benefit of better Machine Learning performances in terms of accuracy: the Deep Learning architecture adopted will be improved (the adopted simple VGG is just a starting point) and trained on a more general and balanced dataset respect to the one adopted for these first experimentations.

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