EEG Assessment of Surprise Effects in Serious Games

Customer

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EXECUTIVE SUMMARY

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Problem area

Many simulations or games used for training purposes require the trainee to make decisions under time pressure, such as handling emergency situations for helicopter pilots. Surprising events are almost always present during emergencies or complex tactical situations. Being able to cope with surprises is an important condition for adequate handling the situation. This work intents to strengthen the role of 'surprises' in simulation games. This report succeeds NLR-TP-2015-004, in which a framework was presented for designing surprises in simulation and gaming. In the current study we examine whether dealing with prior surprises enhances the performance of players and the handling of new, subsequent surprises and whether this can be assessed by electroencephalogram (EEG) measurement of brain activity.

Description of work

In a VBS2 based game, participants were exposed to surprising situations. Measurements were taken real-time from players' left prefrontal cortex, using an EEG device. Two groups of participants were compared at three surprising events during the game, with only one group being exposed to seven preceding surprising events.

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This report is based on a presentation held at the Games And Learning Alliance conference, Rome, December 9-11, 2015.

Results and conclusions

Exposure to surprise events lead to a reduction of power in the delta brainwave band indicating that participants are fully active (no sleepiness or drowsiness). Participants that were exposed to previous surprise events, also have increased power in the Alpha brainwave band, indicating an active but relaxed response to surprises. The results support the use of EEG in assessing surprise effects and provides further indication that exposure to surprise events can help to effectively deal with later surprise events.

Applicability

EEG assessment of surprise effects is a promising technique that can be applied in a wide variety of (military) aviation training, not only emergency training. Two types of EEG applications could bring simulation or gaming to a higher level of effectiveness. First, EEG measures can be used during scenario construction or revision to reject or alter non-effective surprise events. Second, EEG has potential to be used during training sessions to determine current mental states and responses to events. This will support the instructor to adjust the training to optimise learning effects for each individual. At the moment, these applications require some further development before practical use in training is feasible. Data processing and representation needs to be automated before scenario designer and instructor can use EEG results without interfering with their regular tasks.

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Summary

The use of electroencephalograms (EEGs) in assessing surprise effects is a promising technique. Using EEG measures, it was found that exposure to surprise events can help to effectively deal with later surprise events.

This study examines an innovative approach for evaluating surprise effects in a serious game. In this game, players were exposed to surprising situations that challenged their level of performance which eventually should help them to acquire crucial mental readiness when real crisis situations emerge. During exposure to surprises, measurements were taken online from players' left prefrontal cortex, using an electroencephalogram (EEG) device. Two groups of participants were compared at three common surprising events (SEs) during the game, with only one group being exposed to seven preceding SEs. First, mean amplitude power (MAP) values in the Delta band were indeed significantly lower during exposure to SEs compared to their baseline pre-game status which points to a more wakeful state. Secondly, comparing MAP values in the Alpha band showed a significant difference as was expected, with the group with preceding surprises having higher MAPs, indicating less cortical activation which is interpreted as being more relaxed and conscious.

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Content

Abbreviations

Acronym	Description
BCI	Brain Computer Interface
CC	Control Condition
EC	Experimental Condition
EEG	Electro EncephaloGram
MAP	Mean Amplitude Power
NLR	Netherlands Aerospace Centre NLR
NPC	Non Playing Character
PFC	PreFrontal Cortex
REM	Rapid Eye Movement
SE	Surprise Event
SMR	SensoriMotor Rhythm
VBS2	Virtual Battle Space 2 (Bohemia Interactive software)

1 Introduction

Many training contexts in simulation games demand for making decisions under time pressure, such as, for instance, handling emergency situations for helicopter pilots or evacuations for safety personnel. Surprising events are in these circumstances almost always present. Being able to handle them is an important condition for adequate operating and handling the situation. This study intents to strengthen the role of surprises in simulation games, as for example could be used in aviation training. We will first examine whether we can assess surprise effects in brain activity by measuring electroencephalogram (EEG) patterns. Second, we examine whether dealing with prior surprises enhances the performance of players and the handling of new, subsequent surprises.

1.1 EEG measurements

It was only in 1924 when neurologist Hans Berger managed to amplify the brain's electrical activity in order to depict it on a strip of paper. From then on, rapid progress in biofeedback technologies has been achieved, which nowadays allows neuroscientists to examine and analyse various physiological responses concurrently and then correlate them in a unified analysis frame in order to reach robust conclusions such as surprise effects [1]. EEG has been applied for decades to measure differences in mental states. That is what we explore in this study: measuring surprise effects by EEG. Firstly, we will examine whether we can measure reliably surprise effects by EEG when surprising events (SEs) are embedded in a serious game. Secondly, we will test the hypothesis that prior exposure to SEs will lead to more efficient task behaviour in the game (and hopefully in real life) when finally a new SE occurs. Before dealing with the role of surprises in games and the research questions, we will elaborate on the topics of EEG measurements and the nature of surprises.

The human brain generates electricity that can be measured on the scalp surface in microvolts by applying electrodes. Electric output can be found in wavelengths from 0.1 to 100 Hz. This brainwave spectrum is categorized into meaningful bandwidths or brainwave types. Each type has been found to indicate certain psychological states. What is more, each brainwave type is characterized by its amplitude. The more neurons that work in synchrony, the larger the amplitude of the electrical oscillations measured in microvolts. In other words, amplitude indicates the intensity (i.e. power) of the electrical signal at each brainwave type. In a certain interval of time, the Mean Amplitude Power (i.e. MAP) at each brainwave band can be calculated in order to define the mental condition within this time period in general.

Berger was also the first to classify the brainwave spectrum in certain brainwave types in 1929. In general, the most common brainwave bands discussed in EEG literature are Delta, Theta, Alpha, Beta and Gamma [2], each indicating certain mental states (see Table1). However, there is no standard classification of brainwave types. Several frequency ranges for the brainwave bands are used and more detailed classification of the brainwave types have been suggested as well [4], including brainwave types such as Mu (ranging from 7.5 to 12.5 Hz) or SMR (sensorimotor rhythm; ranging for 13 to 15 Hz), each defining very specific brain activity not described by the aforementioned brainwave bands ([5], [6]). A variety of EEG devices (e.g. intrusive or non-intrusive with one or more electrodes) are available in the retail market and manufacturers also define different frequency ranges for these brainwave bands/types for their products and applications. For example, Emotiv defines Delta band for wavelengths ranging from 0.5 to 4 Hz [3], while NeuroSky defines its range from 0.1 to 3 Hz [7].

Table 1. Brainwave types with their respective mental interpretation

Brainwave types		
Brainwave type	**Freq. Range**	**Mental state**
Delta	0.1 to 3 Hz	Deep, dreamless and non-REM sleep, unconscious
Theta	4 to 7 Hz	Intuitive, creative, recall, fantasy, imaginary, dream
Alpha	8 to 12 Hz	Relaxed but not drowsy, tranquil, conscious
Low Beta	12 to 15 Hz	Relaxed yet focused, sensorimotor response
Mid Beta	16 to 20 Hz	Thinking, aware of self and surroundings
High Beta	21 to 30 Hz	Alertness, agitation
Gamma	30 to 100 Hz	Higher mental activity, motor function

NeuroSky's Mindwave Mobile. This study explores the use of non-intrusive EEG. Practical application in training situations using simulation or gaming should be feasible. For that reason a simple one-channel, mobile EEG device measuring frontal brain activity is used, namely Mindwave Mobile (manufactured by NeuroSky Inc.). This device provides a more explicit classification of the Beta band by splitting it into three different brainwave types: Low, Mid and High Beta. Each of these brainwave types is interpreted into a very specific mental state. Table 1 illustrates all bandwidths, as provided by NeuroSky, along with their respective mental state interpretation [7]. The important point now is that Delta activity (0.1 to 3 Hz) corresponds to sleepiness and drowsiness. Specifically, low Delta band means low in sleepiness and thus to be more wakeful [8]. Next to that, Alpha brainwaves (8 to 12 Hz) are generally associated with a state of relaxation [8]. Benca et al. [9] showed that increased Alpha band corresponds to a mental state of more relaxation and consciousness.

Prefrontal cortex. The prefrontal cortex (PFC) is the cerebral cortex which covers the front part of the frontal lobe and it contains Brodmann areas 9, 10, 11, 12, 46, and 47 [10]. Among others, these areas are involved in significant brain functions such as in working memory, decision making, emotion processing, behaviour control, strategy change response, planning and selective attention. In general, the PFC is responsible for executive and higher cognitive functions. Therefore, this part of the brain is the most promising for measuring (short-term and/or long-term) effects that surprises (as well as other emotions) trigger in the brain. Moreover, the frontal activation models [11], [12], [13], [14] argue that the greater the frontal activation, the more intense is the emotional experience.

Frontal EEG asymmetry. Due to frontal EEG asymmetry [15], the left and right parts of the PFC have a different response to emotions with different valence [16], [17], [18]. The right PFC is usually linked to negative emotions such as disgust, fear, sadness which are associated to a basic withdrawal response for dealing with things or situations [19], [20]. Moreover, right frontal asymmetry measures are predictors of empathic concern (compassion and concern), a relationship that is mediated by feelings such as sadness [21]. In addition, right PFC is also associated specifically with the adjustment of inferential learning on the basis of unpredictability (i.e. surprising events) [22]. In contrast, left PFC is usually linked to positive emotions such as joy and happiness which are associated to a basic approaching response of dealing with things or situations [19], [23], [24]. These individual differences in frontal asymmetry are already present in humans from early age and predict their reactivity to emotional challenges [25]. As surprises can have any valence (positive, negative or neutral), they can be partially linked to either left or right PFC activity. Hence, surprises can lead to withdrawal or approach behaviours, or for extreme situations, even fight-or-flight responses [26].

1.2 Nature of surprises

Surprise is a complex phenomenon with physiological and psychological elements and depends considerably on situational meaning and therefore the personal background of the person. Surprising events can trigger a variety of responses such as startle, surprise, confusion, stress, panic, shock, and even trauma.

What counts as a surprise, often defined as inconsistency between predicted and observed outcome [27], differs between individuals in experienced intensity (ranging from insignificant to life threatening). Furthermore, a surprise can have valences such as positive, neutral, or negative, and can be pleasant or unpleasant [28].

1.3 The role of surprises in gaming

Designing surprising events can be done in a variety of ways. We distinguish two main types of surprises: bottom-up surprises, using sensory elements and top-down surprises, using cognitive, narrative elements. A bottom-up surprise is generated by providing unexpected sensory input, while a top down surprise is generated by providing cognitive inconsistencies to Long Term Memory or narrative surprises. Of course a combination of both is also possible.

Visual and auditory cues in the virtual environment can be used in order to create a bottom-up surprise. In the case of visual cues, the surprise of visual stimuli can be more or less salient, determined by features like the local luminance contrast, the colour contrast, the orientation and direction of motion. Moreover, the flickering of a colour (especially red) in some parts of an image can also be surprising and trigger the player's attention [29]. Beside the visual cues that can be used in order to generate bottom-up surprises from the virtual environment, a scenario or game developer can also use auditory cues. Any sudden and unexpected change of tonality, loudness, pitch etc. of voices, music, sounds and noises can cause surprise to the player.

Top-down surprises can be created by building surprises from a narrative or by addressing the personal knowledge base of the trainee(s). For example, assume reading a book in which the main character starts dating a person. The information related to this event becomes surprising when it is coupled to the reader's knowledge in the long-term memory, for example that the person dated is the sister of the person's wife. As a result, the surprise may trigger a physiological reaction such as facial expressions or a cry.

Beside the distinction of surprises on the basis of how they are elicited (bottom-up, top-down or mixed), surprising events can also be related to a task or a procedure that is being executed by a player at the moment or not. In other words, a surprise event can also be either task-dependent or task-independent; one can expect that these surprise types can produce different impact on players. As a result, different types of surprises can be created in a game.

1.4 Research questions and hypotheses

The first research question is whether surprise effects in a game environment can be measured using a simple EEG device. For example, surprises are known for their capability to stir up players, which means that vigilance increases and players transit into an (even) more wakeful state. In EEG, this means lower amplitude power in the Delta band. We therefore expect that inserting Surprise Events (SEs) in the game will lead to lower MAP values in the Delta band compared to a baseline measurement where players were in wakeful rest and no SE's were present. For this reason, Delta band activity will be investigated only for the EC group during baseline and SEs (from Phase B and C). Furthermore, we will compare the online EEG measurements of the SEs with a post-game measurement by means of a questionnaire.

The second research question involves the effect of prior experience with SEs on subsequent handling of new SEs. We expect that the more players are exposed to surprise events the more they will mentally adapt in perceiving and handling SEs, and thus the more efficient they will become during task performance when finally new surprising events occur. The learning process behind this relates to a desensitization process and the formation of a coping strategy [30]. This means less emotional response which during wake state leads to higher Alpha band activity [9]. Therefore, people that have been exposed to SEs before will reveal higher Alpha MAPs when facing with new SEs than people that have not previously been exposed to SEs because previously exposed players will be more relaxed and conscious at that moment. For this reason, the Alpha band activity will be investigated for both groups during Phase C. Furthermore, we expect that people that have been exposed to SEs before, will perform better during new SEs, that is, carry out their mission faster and reach higher in-game scores.

For this purpose, a simulation game including the surprise events mentioned above was designed using Virtual Battle Space (VSB2). A training scenario was developed in which the player acted as an undercover agent who had to perform a series of actions in order to save an island's commercial supplies from terrorists. Two versions were constructed: the Experimental Condition (EC) and Control Condition (CC) version. The scenario was divided into three phases in order to meet the requirements of the study. The first phase (i.e. Phase A) has an introductory purpose to the game and is common for both versions. The goal here is to learn the basic movement keys and the required action-set to the players. The regular gameplay starts at Phase B. At this point, the scenario differentiates the two versions, since seven SEs are introduced for the EC, while no surprises exist for the CC. This is because we want to examine whether being exposed to prior surprises can lead to an improved handling of surprises at a later stage. This later stage is phase C, which is common again for both versions and it introduces the same three SEs. The surprises were inserted within the missions in a random order considering their type. An overview of the two versions of the game is provided in Table 2.

Table 2. Overview of the two versions (Experimental Condition EC; Control Condition CC).

	Phase A	**Phase B**	**Phase C**
EC	Learning basic movement keys, available action-set	Surprising gameplay with **seven** SEs	Surprising gameplay with **three** SEs
CC	Learning basic movement keys, available action-set	Regular gameplay with **no** SEs	Surprising gameplay with **three** SEs

2 Method

2.1 Participants, Conditions of Experiment and Procedure

Twenty people aging from 19 to 33 participated in this experiment (mean age of 10 participants in EC was 24.9, SD=2.870 and mean age of 10 participants in CC was 25, SD=4.137). Assignment to conditions was randomised and balanced to sex and game experience (according to self-ratings from the questionnaires including questions like ‘’how many years of experience do you have in First Person Shooter games and generally in computer games?’ respectively). The experiment took place at the “Serious Game Lab” at the NLR facilities in order to reassure that the setting would be sufficiently quiet. After fitting NeuroSky's Mindwave Mobile to the participants head, they were asked to remain calm and inactive in order to perform a 5 minute baseline recording. When done, verbal instructions related to the gameplay were given to the participants. Afterwards, the participants started playing the mission (either EC or CC) while concurrent EEG recordings were performed. After completing the mission, the participants were handed with a questionnaire that they had to fill in order to complete the experimental process. The total session approximately lasted for about 45 minutes.

2.2 Materials

Game Design. A 3D game scenario was created to provide all types of surprises (described at 1.3) by using the Virtual Battlespace 2 editor from Bohemia Interactive. In this scenario, the player acted as an undercover agent whom had to perform a series of actions in order to save an island’s commercial supplies from terrorists. The gameplay was set as single player, action-based setting using a linear, simple scenario that was playable even for participants unexperienced to first person shooter games.

Fig. 1. Example snapshots from the implemented surprise events

Two different versions of the same mission were implemented. The Experimental Condition (EC) contains 10 surprising events (SEs). Example snapshots from some of the implemented SEs can be seen at Figure 1, i.e. upper-left a sudden fire, at the upper-right an unexpected bomb explosion in a car, lower-left an additional undercover mission is revealed and lower-right the electric provision on the island limits due to a sabotage at the electric generators. The Control Condition (CC) follows the same narrative, except this time only three surprising events are included during Phase C. The two versions are divided in 3 phases (see Table 2):

Phase A: This is the introduction phase where the player learns how to navigate into the virtual world by using the standard gaming control keys for moving around in the virtual environment. Moreover, it is the learning phase where the player becomes aware about his mission and how and which types of actions can be performed. The participant is given guidance (prompts, cues) on the actions to perform. By performing some actions without surprises, we assume the participant will learn to perform the actions setting a baseline of expectations on the task and the environment.

Phase B: For the EC condition this is the surprising events phase, where the player has to perform actions which are introduced by different types of surprising events. The surprising events are introduced as cinematics of certain time duration. On the other hand, in the case of the CC mission, similar cinematics with a neutral character of the same duration are introduced, only this time the surprising stimulus is completely removed because no time differences should exist between the two missions.

Phase C: This is the last “undercover mission” phase, where the player has to perform a series of actions in order to complete the mission successfully. This phase is identical for both EC and CC, since both contain the same (three) SEs.

Analysis Tools and Process. In order to examine the participants’ brain function, EEG data was collected at a sampling rate of 128 Hz by using NeuroSkyLab. By using NeuroSky’s Mindwave Mobile, a dry single-electrode can be applied on the left prefrontal cortex (position Fp1 according to the International 10-20 system [8]), while embedded algorithms on its ThinkGear chipset can perform artefact correction (electricity generated by muscle movements, e.g. eye movements). During gameplay various predefined key-strokes were used in order to time-stamp critical moments (such as the SEs and the game phases) within the EEG recorded data. The recorded data was stored in a Thinkgear file that was converted to a suitable form expressed in microvolts, ranging from -825 to 825 microvolts. Afterwards, EEGLAB was used to further analyse them. In total 40 trials were used in the final analysis (20 trials from baseline recordings and 20 trials from in-game recordings). For the later ANOVA analysis the whole 5 min. baseline rest measurement was used. After defining the proper electrode location, low and high band-pass filtering was applied with respect to the Nyquist frequency restrictions in order to remove remaining artefacts (in addition to the artefact correction of the ThinkGear chipset). When done, specific time-frames of major interest were selected by using the logged time-stamps. A MATLAB script was developed to extract and calculate the MAP values at each (absolute) brainwave band for the selected time-frame using the “spectopo” function.

Before performing statistical analysis over the collected data using the SPSS package, all the epochs (time fragments of 3 seconds) containing outliers were removed by finding the according upper and lower limits for the amplitude range of each brain frequency band [31].

Assessment was performed in-game in order to register the players’ correctness. For this reason, a simple point system was used that measured their total score (+100 points for every correct action). The correct action-set was defined by game-instructors while scoring was automatically logged. During gameplay the players could get feedback and keep track of their progress from the in-game score indicator at the upper-left part of the screen. Moreover, the players’ completion times for finishing a mission were logged (in milliseconds) separately for each phase as well as their overall time for completing the whole mission.

Questionnaire. Besides the EEG and in-game assessment, a post-game questionnaire was used for rating the disturbance in task performance due to the SEs. A 7-point Likert-type scale was used ranging from “not at all” to “very much” disturbed. A screenshot was presented beside each SE, illustrating a scene moment with the SE along with a short description of the respective surprising event.

2.3 Apparatus

The simulation game was made by using the VBS2 Editor (version 1.6) created by Bohemia Interactive Studios. The game was played on a Dell Alienware AURORA_4 desktop computer using an Intel(R) Core(TM) i7-4930K CPU @ 3.40 GHz, with a 27” widescreen monitor, a NVIDIA GeForce GTX 680 graphics card, and a large Alienware headset. The game ran smoothly on a maximum detail (of 2560x1600) and lighting settings. All the VBS2 audio settings (SFX, Music etc.) where set at maximum in order to get advantage of the auditorial cues used in the game. A 64-bit version of Windows 7 Professional was used as operating system. In addition, Neurosky’s Mindwave Mobile was used for collecting the EEG data. This wireless, relatively unobtrusive device consists of the ThinkGear EEG sensor module, one dry-electrode and an ear-clip. Embedded within it is a fully integrated single chip EEG sensor. The chip is programmed with amplification off-head detection, automatic filtering for muscle movements (e.g. eye blinks) and 50/60Hz AC powerline interference. The system calculates the power of two indices (‘meditation’ and ‘attention’) in real time. Characteristics of these indices are kept secret by Neurosky. These propriety indices has not been used in this study. While the Neurosky mindwave has demonstrated practical use for several applications and mental states can be identified accurately [32, 33, 34], its overall validity has not been established conclusively [35, 36].

3 Results

3.1 EEG results

Delta Band Effects. A comparison was made between the mean Delta MAP values during the baseline and during the phases with surprises (Phase B and C) in the EC group. This difference between the baseline (mean amplitude was 431.74, SD=318.38) and each of the Delta's (mean amplitude was 158.71, SD= 234.59) at the moment of the surprises was significant (using One-way ANOVA with Games-Howell for post-hoc analysis showed F(1,9)=14.97, p=.004). We used here a time-window of 3 seconds from presenting the SE's. Figure 2 shows that during the exposure to the SEs the Delta values were lower compared to their baseline pre-game values which point to a more wakeful state.

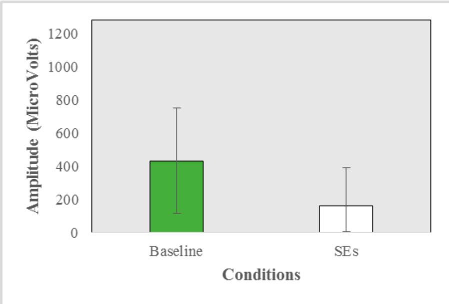

Fig. 2. Mean and standard deviation of MAP Delta values during baseline and SEs.

Alpha Band Effects. Results from the EEG data show a significant difference (t(50.12)=2.08, p<.05; using the Games-Howell calculation for unequal group variance) between the EC group (mean amplitude was 4.28, SD=2.95) and the CC group in Alpha MAP values (mean amplitude was 3.63, SD=2.50). Figure 3 shows that the EC group was more relaxed when encountering surprises in Phase C than the CC group.

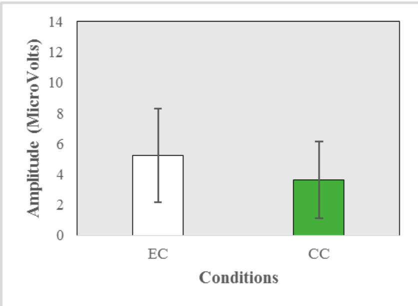

Fig. 3. Mean Alpha MAPs of last three common SEs in the EC and CC groups (Phase C)

3.2 Completion Time and In-game Scores

Next we compared whether participants in the EC group carry out their mission faster than the participants in the CC group, and also we compared their in-game score during phase C. There was a significant difference regarding completion time (t(18)=2.64, p<.005) and regarding in-game performance (t(18)=1.86, p<.05). Figure 4 shows that the EC group was faster (mean time in seconds for EC was 238.53, SD=44.74 while mean time for CC was 301.86, SD=61.35) during Phase C and also their in-game performance score was higher (mean score for EC was a perfect 500, SD=0 while mean score for CC was 450, SD=84.98).

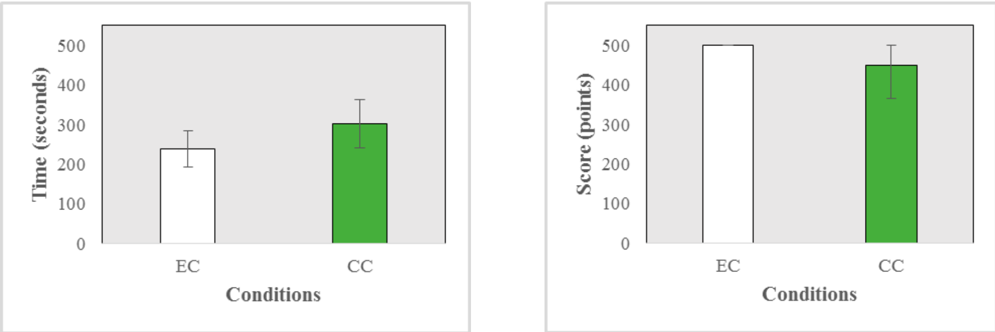

Fig. 4. Means and SD's of Completion time (left) and In-game score (right) during Phase C for both groups.

3.3 Questionnaire Outcomes

Considering the results of the players' self-ratings of disturbance due to task-performance at the post-game questionnaire, no statistically significant differences (p>.05) occurred, during Phase B (mean rating was 2.07, SD=1.71) compared to Phase C (mean rating was 3.32, SD=1.63) for the EC group. Similarly, no significant differences (p>.05) were found among the two groups during Phase C (mean rating for CC group was 3.00, SD=1.57). In figure 5 results are presented.

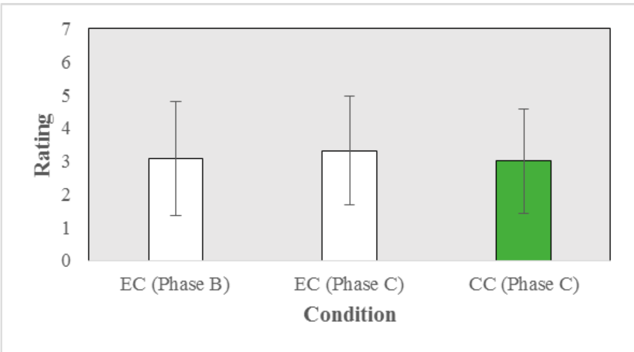

Fig. 5. Means and SD's of players' self-ratings on disturbance during task-performance due to the SE

4 Conclusion and Discussion

Our first research question examined whether the EEG measurement is sensitive and reliable enough to detect EEG effects of surprises. We hypothesized that surprises are considered to stir up players, i.e. to awake them. This hypothesis was confirmed for all surprising events. It appeared that the Delta MAP values were indeed significantly lower during exposure to surprising events compared to their baseline pre-game status, which points to a more wakeful state.

Considering our second research question of whether exposure to more surprises leads to an improved handling of surprises, measurements were performed in three ways: EEG measurements, in-game measurements and post-game questionnaire ratings. The results showed that even though the EC participants stated not to feel less disturbed during their task-performance based on the questionnaire compared to the CC group, they still performed better regarding their in-game performance and completion time during Phase C. When looking at the EEG results of the two groups during the surprising events within a 3 seconds time-window from the moment the last three common SEs were presented, the EC and CC groups differed in Alpha band, indicating that the EC group felt more relaxed than the CC group during Phase C. This fact probably helped the EC group to maintain a higher level of instant or reflex reactions towards the surprising gameplay, which consequently facilitated to achieve higher in-game scores and faster completion time.

The study mainly focused on testing the usefulness of one technique that has powerful potential in online measuring mental states: EEG measurement. With the device as used, surprises could be detected and distinguished in a virtual simulation environment. This outcome can also be used in revising/redesigning processes of a surprising scenario's, that is, it enables designers to reject or alter non-effective surprising events. Based on the results of this study we conclude that even a simple, commercial of the shelf tool that is easy to use in standard training situations, is sensitive and reliable to measure effects to surprising events. However, using the data recording and analysis software is at present not a simple task and considerable time and effort must be spent.

No matter the complexity that EEG measurement introduced in this experiment, it helped in answering the posed research questions. An important finding is the effect of surprises in the Delta band, more specifically its MAP value decreased when SEs were triggered. The most significant finding, however, was the increased Alpha band activity after being exposed to many surprises, implying that the players responded emotionally less intensive to later surprising stimuli leading to a relaxed and more conscious mental state. This is probably also the reason why they managed to be more effective during task performance. However, the post-game questionnaire results didn't align with these in-game and EEG findings. Therefore, doubts can be raised for the usefulness of a post-game questionnaire, at least as it was currently constructed.

This experiment was also an excellent chance for us to test our simulation game for assessment and training purposes. As for the simulation game used for assessment and training it is important to mention that the use of EEG provided a new scope in the analysis of players' mental states. However, what also could be (additionally) useful here is an eye-tracking device and a camera for recording facial expressions. An eye-tracking device would allow observation of the participants' reaction to surprises. Additionally, more biofeedback devices such as Galvanic Skin Response could also be used, with the trade-back however of possibly decreasing the players' immersion and natural response. While a one-channel device is easy to wear, more channels do provide more information. For example, it could be useful to examine the right prefrontal cortex since in the current scenario setting only surprises of neutral and negative valence were implemented and these are mainly represented at the left prefrontal cortex.

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