Kellyann Stamp, Chelsea Dobbins, Stephen Fairclough and Helen Poole, "The Influence of Game Demand on Distraction from Experimental Pain: A fNIRS Study" in the 2nd International Neuroergonomics Conference, Philadelphia, PA, USA, June 27-29, 2018 (Accepted)

The Influence of Game Demand on Distraction from Experimental Pain: A fNIRS Study

Background

Video games are the most effective form of distraction from procedural pain compared to other distraction techniques, such as watching television or reading a book (Hussein, 2015). The degree of cognitive engagement with the game is a strong influence on the capacity of game-playing to distract from pain. By increasing game demand to a level that demands maximum levels of attention, it is possible to optimise distraction from pain; however, if the game becomes too difficult, it will fail to act as a distraction.

Goals and Hypotheses

The goal of this study was to measure neurovascular activation in prefrontal and somatosensory areas of the cortex in response to a manipulation of game demand and experimental pain. We hypothesise that activity in the prefrontal cortex will increase with game demand whereas neurovascular activation of the somatosensory cortex will intensify in the presence of pain.

Methodology

Participants

20 participants (6 female) with a mean age of 22 volunteered for the study.

Game

The game *Space Ribbon,* a racing game developed by Onteca, was used during this experiment. Four pre-set levels of game difficulty, determined by pilot testing, were used: Easy, Medium, Hard, and Impossible.

Cold Pressor Test

The Cold Pressor Test was used to induce experimental pain. The cold pressor apparatus included a tank of water at a fixed temperature of 2°c, in which the participant placed the foot. Cold pressor immersions were performed on both feet over the course of the experiment.

Data Collection Materials

Functional Near Infrared Spectroscopy (fNIRS) was used in this experiment to measure the neurological responses to game demand and pain. fNIRS data was collected using the Artinis Oxymon Mk II system in a 2x4 Cross channel configuration. A total of 2 sources and 8 detectors were used for the collection of optical density data. Data was collected from the prefrontal cortex at channels between Fz and: F1, AFZ, F2 and FCZ, and the somatosensory cortex at channels between CPZ and: CP1, Cz, CP2 and Pz. Accelerometer data was collected from a Shimmer 3 unit, which was worn around the head to collect head motion artefacts. Electrocardiogram data was collected from a Bioharness 3, which was worn around the torso.

Procedure

In order to ensure that data collected during each step of the experiment protocol was independent of the effects from previous steps, a 90 second baseline period was established. The experiment was carried out using the following protocol:

1. Baseline
2. Cold Pressor Immersion
3. Baseline
4. Cold Pressor Immersion with Game Condition
5. Baseline

6. Game Condition (With the same difficulty level as experienced during step 4)

These six steps were repeated four times to account for four levels of game difficulty. The levels of game difficulty were played in a randomised order.

During a cold pressor immersion, the participant was instructed to remove their foot from the water when they felt as though the pain they were experiencing was unbearable, up to a limit of 3 minutes.

Pre-Processing

Following the conversion of optical density data to Oxygenated and Deoxygenated Haemoglobin changes using the modified Beer Lambert Law, fNIRS data was filtered using a 6^{th} order Chebyshev filter. This filter was applied to remove physiological noise, and to remove the effect of Mayer waves (Noori, Qureshi, Khan, & Naseer, 2016).

Accelerometer data was filtered using a Butterworth filter, to reduce noise in the signal. Following data filtering, fNIRS data was processed alongside accelerometer data using the Acceleration-Based Movement Artefact Reduction Algorithm (Metz, Wolf, Achermann, & Scholkmann, 2015) to remove head motion artefacts.

Results

Subjective measures of workload (Task Load Index) and immersion (Immersive Experience Questionnaire) were collected as manipulation checks. Subjective mental workload [$F(1,17)=9.78, p<.01, eta^2= 0.66$] and immersion [$F(1,17)=4.94, p<.01, eta^2= 0.47$] both significantly increased as game demand was escalated.

The amount of time that participants immersed their foot in the cold water was used as a behavioural measure of pain tolerance. An ANOVA revealed that: (1) playing the game significantly increased pain tolerance compared to baseline (no game), and (2) pain tolerance increased during Medium/Hard/Impossible games compared to the Easy game [$F(3,11)=2.07, p<.01, eta^2= 0.66$].

A 2 (pain/no pain) x 4 (easy/medium/hard/impossible demand) x 4 (Fz-F1/Fz-F2/Fz-AFz/Fz-FCz) ANOVA was conducted on oxygenated (Hb0) and deoxygenated (Hbb) haemoglobin. The analysis of Hb0 data revealed a significant interaction between channel and demand [$F(9,8)=5.23, p<.01, eta^2= 0.86$], post-hoc testing indicated that Hb0 significantly increased from Medium to Impossible demand at Fz-F2. The same ANOVA also revealed a significant interaction between channel and condition [$F(3,14)=3.93, p<.03, eta^2= 0.20$], i.e. Hb0 was higher at Fz-F1 when participants played the game in the presence of experimental pain. No significant effects were observed for Hbb. An identical analysis was conducted on Hb0 and Hbb from the somatosensory cortex. A significant interaction between channel and condition was observed for Hb0 [$F(9,14)=2.79, p<.05, eta^2= 0.15$]; post-hoc tests indicated that Hb0 was significantly higher at CP1-CPz during the experimental pain condition.

Conclusions

The study demonstrated that game demand exerted a significant effect on pain tolerance in the expected direction, i.e. increased demand = increased distraction and pain tolerance. Our fNIRS data revealed a significant lateralised effect of game demand and experimental pain on levels of Hb0 in the prefrontal cortex, i.e. the former was localised to the right hemisphere with the latter observed on the left side. As expected, levels of Hb0 in the somatosensory cortex increased in the presence of pain but were not affected by game demand.

The study demonstrates the feasibility of developing a neuroadaptive game engine capable of adjusting game demand in real-time in order to maximise distraction from pain.

References

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