Using fNIRS to Measure Emotions in Simulation Training

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ABSTRACT

This paper reviews applied and theoretical research regarding neural activity in simulated learning environments. The focus will be on psychological/emotional fidelity. The capabilities of using fNIRS technology to measure progress during psychological/emotional training in simulated environments will be demonstrated. Activity in the prefrontal cortex may be able to differentiate learning performance between novice trainees and experienced trainees in emotionally charged training scenarios.

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BACKGROUND

Simulation training uses technology to replicate real-world performance contexts in athletic, military, education, medical, and other domains. This technology may involve the use of live scenarios with trainers, the capturing of performance data, or virtual or augmented reality.

When designing or selecting a simulator, stakeholders and end-users must decide which aspects of the simulation are most important. Aspects of the simulation may be categorized according to levels of fidelity. *Fidelity* refers to the accuracy of representation of the true 'real world' of the simulation. Fidelity in simulations can be delineated into sub-categories: environmental (i.e. visual, audio, haptic), equipment (realism regarding the cognitive aspects of the task) and psychological (emotional) fidelity (Rehmann, Mitman, & Reynolds, 1995). This review will focus on the ability of fNIRS (functional near-infrared spectroscopy) capability to measure psychology fidelity in simulations.

PSYCHOLOGICAL FIDELITY

Designing a training simulation with psychological fidelity is crucial because aspects of the environment that impact psychological processes will impact performance (Kozlowski & DeShon, 2004). For example, stress can adversely affect cognitive processes devoted to divided attention, working memory, retrieval of information from memory, and decision-making (LeBlanc, 2009).

Emotional Fidelity

Emotional fidelity is a form of psychological fidelity. Psychological fidelity is the replication of aspects of the environment for performance in real-world settings; emotional fidelity is the simulation's capability to elicit an affective reaction from a trainee. Emotional fidelity may include but is not limited to constructs such as camaraderie, trust, and frustration. Events or key performance characteristics that may be relevant to real-world settings for emotional fidelity training can be for example, overcoming shock, coping with repercussions, loss mitigation, and moral decision-making.

BRAIN IMAGING

Measuring cortical activity in real time during training sessions provides a window into emotional fidelity. Functional near-infrared spectroscopy (fNIRS) is a portable device that noninvasively measures the oxygenated and deoxygenated hemoglobin responses in the scalp (Ayaz, Izzetoglu, Izzetoglu, & Onaral, 2019). Given its portability measuring cortical activity in ecologically valid settings is an ideal application of fNIRS. fNIRS is useful for affective-state monitoring in simulation as it has been used to evaluate the effects of negative mood states on working memory (Hani, Feng, & Tang, 2018) and to infer the emotional states of users while they are at work (FakhrHosseini, Jeon, & Bose, 2015).

The aim of this review is to evaluate fNIRS ability to measure brain activity linked to emotional fidelity within a simulation training environment. Additionally, the ability of fNIRS to determine changes in emotional processing as a result of skill acquisition/increased levels of expertise will be discussed. Emotions play a role in knowledge acquisition that can be generalized to performance contexts (DeMaria Jr et al., 2010). Tracking neural behavior for psychological fidelity may ultimately give a better understanding of how established performance is for individual trainees.

fNIRS

In terms of cognitive activity, fNIRS have been successful in the assessment of cognitive control, risk taking and moral decision-making linked with motor task performance (Skurvydas et al., 2018), threat evaluation in visual attention (Bendall, Eachus, & Thompson, 2016), the impact of negative emotion on working memory (Ozawa, Matsuda, & Hiraki, 2014), and have monitored sustained attention to detect performance degradation (Derosière, Mandrick, Dray, Ward, & Perrey, 2013; Mandrick et al., 2013). fNIRS have also mapped changes in cortical activity when a trainee is acquiring expertise. This has been shown in simulated piloting tasks (Ayaz et al., 2012). Additionally, fNIRS have the capability to detecting changes in PFC activity associated with increases and decreases in difficulty during simulated training tasks (Mark et al., 2017).

fNIRS have detected emotional generation and emotional regulation states. Emotional processing in fNIRS can be divided by looking at PFC activity "during task completion where naturally occurring emotion is recorded or artificially induced" (Bendall, Eachus, and Thompson, 2016). fNIRS research shows mixed results. There are similar responses for measuring positive and negative stimuli. Additionally fNIRS used to measure the same cognitive tasks can have different results. It has been argued that experimental design explains these mixed results (Bendall, Eachus, and Thompson, 2016).

fNIRS research has pinpointed the right ventrolateral prefrontal cortex as an appropriate area to measure emotional generation in stress responses (Al-Shargie, Tang, & Kiguchi, 2017), anger responses in drivers (FakhrHosseini et al., 2015), and the emergence of "flow states" during gameplay (Tetris)(Yoshida et al., 2014). Research with fNIRS, have shown that positive and negative emotional states are represented through asymmetric prefrontal activity. Differences in right-left prefrontal activity are shown to be dependent on the valence (positive or negative) of photographic stimuli (Balconi, Grippa, & Vanutelli, 2015)

For activity during 'higher order' functions, fNIRS have been linked to suppression of negative emotion (emotional regulation) during aspects of interpersonal communication (Honda, Tanaka, Sakti, & Nakamura, 2018) fNIRS have also been used for higher level processes, such as detecting differences in personal and impersonal moral judgments (Dashtestani et al., 2018). For example, using fNIRS, researchers measured changes in the DLPFC while participants deliberated choices during a business-oriented moral dilemma task with the added pressure of time constraint. The moral dilemmas were structured similarly to the Trolley Car dilemma; the goal of the decision maker must choose the least harmful decision rather than avoid negative repercussions altogether. Situations such as insider trading, questionable research practices and corporate tax cases were presented to participants. Bilateral increases of values in the DLPFC were observed from subjects who made moral decisions under time constraint. The results suggest that severe time constraint can lead to cognitive overburden, elevating decision stress, possibly leading to moral incompetency (Lee & Yun, 2017).

Cognitive Control

Cognitive control is the ability to regulate emotion, influence attentional processes. It is the mechanism in which individuals recruit and engage regulatory processes in order to modulate reactions from emotional stimuli (Ochsner & Gross, 2005). Cognitive control occurs along the rostral caudal axis of the frontal cortex, with complexity increasing in the rostral direction (Badre, 2013). Rostral regions of the frontal cortex are associated with contextual and abstract information processing. In particular, these abilities are linked to policy abstraction, which is the brains ability to process environmental cues, then take rules and apply them in different contexts. These rules can be "first order" relating to the shape or another feature of the cue, or the rule can be "second order" relating to a more abstract rule, such as which "first order" rule to use when analyzing the task or environment (Badre, 2013). Interestingly, negative emotional stimuli modulates activity in the cognitive control network (Jasinska et al., 2012). The impact of the valence of stimuli (positive or negative) has been measured through hemispheric asymmetry. Valence (pleasantness) of stimuli creates hemisphere dominant cognitive activity. The right hemisphere has been linked to unpleasant stimuli, and the left with pleasant stimuli (Spielberg, Stewart, Levin, Miller, & Heller, 2008).

EMOTIONAL FIDELITY AND SIMULATION TRAINING

Conflicting evidence exists regarding the impact of emotions on training and performance. This has been especially demonstrated in medical simulation. During trauma resuscitation simulations, medical residents' subjective stress ratings and cortisol levels were significantly higher in high stress simulations than low stress simulations. In addition, it showed that simulation performance scores and postscenario recall (immediately after scenario) was significantly lower in the high stress simulation (Harvey, Bandiera, Nathens, & LeBlanc, 2012). Along these same lines, a group of 116 medical students exposed to unexpected patient (SimMan 3-G; Laerdal Medical) death during a toxin ingestion management simulation found an increase in self-reported cognitive load compared to students that were not exposed to unexpected death. Three months later, during a follow-up evaluation using a simulated patient (SimMan 3-G; Laerdal Medical) the unexpected death group received lower ratings in reference to their capability of diagnosing and managing patients' with altered levels of consciousness due to toxin ingestion (Fraser et al., 2014).

However, there is evidence that emotion introduced during simulation training can enhance long-term knowledge retention. In another study involving medical students, advanced cardiac life support (ACLS) skills were taught using a simulated patient (METI HPS; Medical Education Technologies, Inc.). It was shown that the introduction stress via dialogue from study confederates increased self-reported anxiety levels and led to better ACLS knowledge evaluation scores six months later (DeMaria Jr et al., 2010). The positive effect of emotionality in simulation training on recall has been reinforced in military research. The impact of sound on participants' recall and physiological responses (temperature, electro dermal response, and heart-rate) during a first-person shooter desktop training game, *America's Army: Operations (AA:O)* were measured. Physiological measures of participants in the sound condition indicated higher arousal. Furthermore, participants in high audio emotionality conditions had significantly better item recall in virtual environments than participants in low emotionality (no noise) conditions (Shilling, Zyda, & Wardynski, 2002). In another military study that used *America's Army: Operations (AA:O)*, the presence of combat differentiated high emotional arousal from low emotional arousal (no combat) (Ulate, 2002). Players in the high emotional arousal conditions (combat) performed better on recalling objects in the virtual environment immediately and 24 hours after the experiment.

EXPERTISE

The impact of emotion on performance is modulated by experience. Outside of simulation research, performance differences have been measured with experience in commodities traders. Experienced traders had greater heart-rate variability than less experienced traders. Research cites emotional regulation as a consideration for physiological as well as performance differences seen in the participants. High performing traders had more effective emotional regulation than equivalently experienced but lower-performing traders (Fenton-O'Creevy et al., 2012).

Differences in cortical activity of experts and novices have also been established. Using fMRI during compassion meditative exercises, blood-oxygen-level dependent (BOLD) signals in the insula coupled with increased heart rate was modulated by the type of meditation as well as level of expertise (Lutz, Greischar, Perlman, & Davidson, 2009).

An fMRI study explicitly compared elite (medalists from the Olympics, Asian Games, and World Championships), expert (college athletes from the Korean Archery Association) and novice archers (college students) during aiming and found that expertise was associated with highly localized neural activity, particularly in the prefrontal cortex. During aiming, right before archers took their shot, novice archers showed activity in the dorsolateral pre-motor cortex and the ventral pathways linked to the ventrolateral pre-motor cortex. Elite archers showed activity in the supplementary motor area, temporoparietal area, and cerebellar dentate, and expert archers showed activity only in the superior frontal area. The localization of brain activity indicates greater neural efficiency. In particular, the involvement of the cerebellar dentate in expert archers is theorized to be a result of the cerebellum's role in automating movement (Kim et al., 2014).

Expertise is defined as an increase in automaticity for specified task performance. This increase in automaticity has been illustrated using fNIRS. An eight-day study measured the effect of training for piloting unmanned aerial vehicles. Subjective mental effort and performance evaluation was assessed using the NASA Task Load Index

(TLX) questionnaire. The average total hemoglobin concentration changes throughout the practice levels (beginner /intermediate /advanced) assessed changes in workload as a result of practice and level of difficulty of the flight simulator. An inverse relationship between workload and task demands was illustrated through neural behavior in the frontal lobe. That is, “the development of expertise is the freeing up of limitations on attentional resources” (Ayaz et al., 2012).

Neural Efficiency

The basis of the neural efficiency hypothesis is that higher skilled/intelligent individuals recruit less cognitive resources to complete critical thinking tasks. Neural efficiency can predict differences in brain activation during cognitive tasks based on level of expertise and can be linked to higher level mental abilities such as decision-making and conflict resolution (Di Domenico, Rodrigo, Ayaz, Fournier, & Ruocco, 2015). The more practiced or intelligent a person is, the less resources their brain uses to complete a task (Haier et al., 1988).

Neural efficiency has been linked to emotional processing. More specifically, *neurally efficient behavior in the prefrontal cortex has been associated with measures of cognitive control*. Sex differences in the cognitive reappraisal process of emotion regulation were demonstrated by neural efficiency using fMRI. Compared with women, men had less activity in the prefrontal cortex during emotional regulation. Indicating that men have greater automatic emotion regulation than women (McRae, Ochsner, Mauss, Gabrieli, & Gross, 2008). Aside from sex-based generalizations on cortical behavior, individual differences in neural efficiency and cognitive control have also been illustrated using fMRI measures of the dorsolateral prefrontal cortex. Highly anxious individuals start out with lower neural efficiency, which modulates inhibitory control. These anxious adults have impaired neural efficiency during processes that require attentional control (Stroop task) regardless of whether or not there is a threat present (Basten, Stelzel, & Fiebach, 2011).

CONCLUSIONS

fNIRS are valuable in evaluating current simulation outcomes and improving simulation techniques. However, there is room for improvement and clear considerations in order to progress in the use of fNIRS to measure emotional fidelity in simulation training. This review highlighted fNIRS research on emotional fidelity, management of emotions, the value of emotional fidelity in simulation, and the ability of fNIRS to determine changes in emotional processing as a result of skill acquisition/increased levels of expertise. The importance of emotional fidelity for simulation training was illustrated through literature, which showed that emotions have the possibility of impairing or enhancing performance and cognition. The value of fNIRS as a modality for measuring brain activity in simulated training environments is supported by anatomical regions in the prefrontal cortex linked to specialized areas in cognitive processing. fNIRS value in simulated training is also demonstrated by research pertaining to cognitive control and emotional regulation. Furthermore, cortical activity using fNIRS show differences in experienced versus inexperienced trainees. And, hemodynamic changes during the acquirement of expertise are measurable with fNIRS. This review also presented literature verifying that differences in processing/performance capabilities in emotionally salient scenarios are measurable in the prefrontal cortex. These differences can be measured within subject groups (e.g. male and female) as well as individually.

The ability of fNIRS track biomarkers for individual differences is extremely valuable. This capability can be used in order to build adaptive tutoring systems in ecologically valid training settings. It has been shown that it is possible to use fNIRS to build predictive trainers and that individual differences can be accounted for using emotional processing biomarkers. With regards to progress in simulation training and intelligent tutoring, hemodynamic changes resulting from emotion inducing stimuli can be accurately classified for a BCI interface (Tai & Chau, 2009).

Training can be adapted to meet the progress of trainees. For example, neurofeedback has been used in a flight simulator with adapting levels of difficulty in order to optimize learning according to the experience of trainees (Mark et al., 2017). Using and measuring psychological and emotional fidelity can help to train for individual differences in personnel selection, and establish baselines for monitoring systems in brain computer interfaces. However, more work must be done to differentiate training requirements between novices and experts. This includes ascertaining the neural mechanisms required for higher-level training goals such as moral and rational decision-making. Additionally, there is a paucity of work regarding the capability of fNIRS to measure decision-making in reference to reactive decision-making (i.e. in the face of repercussions).

There is room for improvement in fNIRS research. The problems surrounding measuring emotional processing via fNIRS has been outlined via cognitive tasks. One of which is lack of standardization concerning the inclusion of different conditions. Some studies have positive, negative, and neutral conditions. And, some studies have only positive and negative conditions. This creates difficulty when comparing results (Bendall et al., 2016). Additional difficulty in comparing fNIRS studies is that certain studies analyze at the group level, while others analyze at the individual level, showing the importance of individual differences in emotion cognition studies.

Consideration also needs to be paid to the simulation modality. Some training technologies may be easier to immerse the trainee (e.g. live or virtual reality simulations) and have easier ways to integrate emotional fidelity to obtain the desired response. Furthermore, level of experience of the trainee may impact emotional "buy-in." For example, a surgical simulation may not elicit the same reaction in an experienced surgeon as it would in a trainee who has never stepped foot in an operating room. This introduces challenges regarding the measurement or creation of standards within simulation based research.

However, this statement begs the question: *By repeatedly exposing a trainee to a simulated environment in order to obtain data regarding their adaptation and performance in the simulated environment, are we just training to become better at training?* This is not a new question, and is relevant for all behavioral based research. This has been highlighted succinctly in a paper that established fNIRS ability to detect changes in blood oxygenation levels as a result of mental effort. "It remains to be seen whether individuals who demonstrate high neural efficiency in laboratory cognitive tasks can demonstrate the same level of efficiency in real-world activities" (Causse, Chua, Peysakhovich, Del Campo, & Matton, 2017).

The details of this review aimed to expand upon research concerning the feasibility of using fNIRS for "big picture" training objectives such as moral decision-making, strategic decision-making, loss mitigation, or communication enhancement as well as more nuanced training objectives such as stress management. However, it is important to distinguish literature that uses emotion/stress as a result of the simulation/training versus specifically eliciting emotion/stress as a result of the design of the simulation. Regarding the efficacy of emotions in simulations, this is an interesting question where two research avenues diverge. On one hand, results of studies indicate that emotional distractors (such as threats) enhance cognition. On the other hand, some research indicates that emotional distractors impair cognition. This area warrants further investigation.

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REFERENCES

Al-Shargie, F., Tang, T. B., & Kiguchi, M. (2017). Assessment of mental stress effects on prefrontal cortical activities using canonical correlation analysis: an fNIRS-EEG study. *Biomedical optics express, 8*(5), 2583-2598.

Ayaz, H., Çakir, M. P., İzzetoğlu, K., Curtin, A., Shewokis, P. A., Bunce, S. C., & Onaral, B. (2012). *Monitoring expertise development during simulated UAV piloting tasks using optical brain imaging.* Paper presented at the 2012 IEEE Aerospace Conference.

Ayaz, H., Izzetoglu, M., Izzetoglu, K., & Onaral, B. (2019). The Use of Functional Near-Infrared Spectroscopy in Neuroergonomics *Neuroergonomics* (pp. 17-25): Elsevier.

Badre, D. (2013). Hierarchical cognitive control and the functional organization of the frontal cortex. *The Oxford Handbook of Cognitive Neuroscience, 2*, 300-317.

Balconi, M., Grippa, E., & Vanutelli, M. E. (2015). What hemodynamic (fNIRS), electrophysiological (EEG) and autonomic integrated measures can tell us about emotional processing. *Brain and cognition, 95*, 67-76.

Basten, U., Stelzel, C., & Fiebach, C. J. (2011). Trait anxiety modulates the neural efficiency of inhibitory control. *Journal of cognitive neuroscience, 23*(10), 3132-3145.

Bendall, R. C., Eachus, P., & Thompson, C. (2016). A brief review of research using near-infrared spectroscopy to measure activation of the prefrontal cortex during emotional processing: the importance of experimental design. *Frontiers in Human Neuroscience, 10*, 529.

Causse, M., Chua, Z., Peysakhovich, V., Del Campo, N., & Matton, N. (2017). Mental workload and neural efficiency quantified in the prefrontal cortex using fNIRS. *Scientific reports, 7*(1), 5222.

Dashtestani, H., Zaragoza, R., Kermanian, R., Knutson, K. M., Halem, M., Casey, A., Gandjbakhche, A. (2018). The role of prefrontal cortex in a moral judgment task using functional near-infrared spectroscopy. *Brain and behavior, 8*(11), e01116.

DeMaria Jr, S., Bryson, E. O., Mooney, T. J., Silverstein, J. H., Reich, D. L., Bodian, C., & Levine, A. I. (2010). Adding emotional stressors to training in simulated cardiopulmonary arrest enhances participant performance. *Medical education, 44*(10), 1006-1015.

Derosière, G., Mandrick, K., Dray, G., Ward, T. E., & Perrey, S. (2013). NIRS-measured prefrontal cortex activity in neuroergonomics: strengths and weaknesses. *Frontiers in Human Neuroscience, 7*, 583.

Di Domenico, S. I., Rodrigo, A. H., Ayaz, H., Fournier, M. A., & Ruocco, A. C. (2015). Decision-making conflict and the neural efficiency hypothesis of intelligence: A functional near-infrared spectroscopy investigation. *Neuroimage, 109*, 307-317.

FakhrHosseini, M., Jeon, M., & Bose, R. (2015). *Estimation of drivers' emotional states based on neuroergonmic equipment: an exploratory study using fNIRS.* Paper presented at the Adjunct Proceedings of the 7th International Conference on Automotive User Interfaces and Interactive Vehicular Applications.

Fenton-O'Creevy, M., Lins, J. T., Vohra, S., Richards, D. W., Davies, G., & Schaaff, K. (2012). Putting emotion at the heart of finance: Emotion regulation and trader expertise.

Fraser, K., Huffman, J., Ma, I., Sobczak, M., McIlwrick, J., Wright, B., & McLaughlin, K. (2014). The emotional and cognitive impact of unexpected simulated patient death: a randomized controlled trial. *Chest, 145*(5), 958-963.

Haier, R. J., Siegel Jr, B. V., Nuechterlein, K. H., Hazlett, E., Wu, J. C., Paek, J., Buchsbaum, M. S. (1988). Cortical glucose metabolic rate correlates of abstract reasoning and attention studied with positron emission tomography. *Intelligence, 12*(2), 199-217.

Hani, A. F. M., Feng, Y. X., & Tang, T. B. (2018). Negative Mood States in Neuroergonomics *Neuroergonomics* (pp. 325-326): Elsevier.

Harvey, A., Bandiera, G., Nathens, A. B., & LeBlanc, V. R. (2012). Impact of stress on resident performance in simulated trauma scenarios. *Journal of Trauma and Acute Care Surgery, 72*(2), 497-503.

Honda, M., Tanaka, H., Sakti, S., & Nakamura, S. (2018). *Detecting suppression of negative emotion by time series change of cerebral blood flow using fNIRS.* Paper presented at the 2018 IEEE EMBS International Conference on Biomedical & Health Informatics (BHI).

Jasinska, A. J., Yasuda, M., Burant, C. F., Gregor, N., Khatri, S., Sweet, M., & Falk, E. B. (2012). Impulsivity and inhibitory control deficits are associated with unhealthy eating in young adults. *Appetite, 59*(3), 738-747.

Kim, W., Chang, Y., Kim, J., Seo, J., Ryu, K., Lee, E., Janelle, C. M. (2014). An fMRI study of differences in brain activity among elite, expert, and novice archers at the moment of optimal aiming. *Cognitive and Behavioral Neurology, 27*(4), 173-182.

Kozlowski, S. W., & DeShon, R. P. (2004). A psychological fidelity approach to simulation-based training: Theory, research and principles. *Scaled worlds: Development, validation, and applications*, 75-99.

Lee, E.-J., & Yun, J. H. (2017). Moral incompetency under time constraint. *Journal of Business Research*.

Lutz, A., Greischar, L. L., Perlman, D. M., & Davidson, R. J. (2009). BOLD signal in insula is differentially related to cardiac function during compassion meditation in experts vs. novices. *Neuroimage, 47*(3), 1038-1046.

Mandrick, K., Derosiere, G., Dray, G., Coulon, D., Micallef, J.-P., & Perrey, S. (2013). Prefrontal cortex activity during motor tasks with additional mental load requiring attentional demand: a near-infrared spectroscopy study. *Neuroscience research, 76*(3), 156-162.

Mark, J., Thomas, N., Kraft, A., Casebeer, W. D., Ziegler, M., & Ayaz, H. (2017). *Neurofeedback for Personalized Adaptive Training.* Paper presented at the International Conference on Applied Human Factors and Ergonomics.

McRae, K., Ochsner, K. N., Mauss, I. B., Gabrieli, J. J., & Gross, J. J. (2008). Gender differences in emotion regulation: An fMRI study of cognitive reappraisal. *Group processes & intergroup relations, 11*(2), 143-162.

Ochsner, K. N., & Gross, J. J. (2005). The cognitive control of emotion. *Trends in cognitive sciences, 9*(5), 242-249.

Ozawa, S., Matsuda, G., & Hiraki, K. (2014). Negative emotion modulates prefrontal cortex activity during a working memory task: a NIRS study. *Frontiers in Human Neuroscience, 8*, 46.

Rehmann, A. J., Mitman, R. D., & Reynolds, M. C. (1995). *A Handbook of Flight Simulation Fidelity Requirements for Human Factors Research*. Retrieved from

Shilling, R., Zyda, M., & Wardynski, E. C. (2002). *Introducing emotion into military simulation and videogame design: America's Army: Operations and VIRTE.* Paper presented at the Proceedings of the GameOn Conference.

Skurvydas, A., Valančiene, D., Šatas, A., Mickevičiene, D., Vadopalas, K., & Karanauskienė, D. (2018). Are Motor and Cognitive Control, Impulsivity and Risk-Taking Behavior as well as Moral Desicion Making Determined by the Activity of Prefrontal Cortex During Stroop Test? *Baltic Journal of Sport and Health Sciences, 1*(108).

Spielberg, J. M., Stewart, J. L., Levin, R. L., Miller, G. A., & Heller, W. (2008). Prefrontal cortex, emotion, and approach/withdrawal motivation. *Social and personality psychology compass, 2*(1), 135-153.

Tai, K., & Chau, T. (2009). Single-trial classification of NIRS signals during emotional induction tasks: towards a corporeal machine interface. *Journal of neuroengineering and rehabilitation, 6*(1), 39.

Ulate, S. O. (2002). *The impact of emotional arousal on learning in virtual environments.* Monterey, California. Naval Postgraduate School.

Yoshida, K., Sawamura, D., Inagaki, Y., Ogawa, K., Ikoma, K., & Sakai, S. (2014). Brain activity during the flow experience: A functional near-infrared spectroscopy study. *Neuroscience letters, 573*, 30-34.