Effects of Immersive Technology on Affective Constructs during Physical Activity

Harold Kwong

September 21, 2025

1 Introduction

There is strong evidence linking physical activity with numerous health benefits, including prevention and management of diabetes, heart disease, and even some cancers (Santos et al., 2023). However, reports of physical inactivity and sedentary behaviour remain prevalent among the general population, preventing them from receiving the health benefits associated with physical activity (Schultchen et al., 2019). Accordingly, there is a need for evidence-based interventions to encourage physical activity. It is increasingly recognised that affective constructs (i.e., feeling states) may have the potential to be more effective than cognitive constructs (e.g., self-efficacy) in motivating individuals to complete physical activity (Ekkekakis et al., 2021).

1.1 ***Core Affect and Dual Mode Theory***

Central to this project is the notion of core affect and the Dual Mode Theory (Ekkekakis, 2003). Core affect refers to the feelings perceived during an activity, which is indicative of whether that activity will be repeated (Russell, 1980). Core affect is comprised of affective valence (*ranging from negative to positive*) and arousal (*ranging from low to high*). Analysing these variables in tandem allows us to depict the overall feeling that is perceived during an activity (Rhodes & Kates, 2015).

According to the Dual Mode Theory, how people feel during exercise is a product of the intensity of that exercise and can be broken down using metabolic markers such as gas-exchange ventilatory threshold (VT) and respiratory compensation point (RCP) (Ekkekakis, 2003). Below VT, affective valence is generally positive in healthy individuals. Between VT and RCP, affective valence is varies between individuals, with some remaining in a positive state and some falling below to the negative state. Beyond RCP, the majority of individuals will show a decline in affective valence (Ekkekakis et al., 2020). This project targets the phase between VT and RCP, specifically during lifestyle physical activity, which is unintentional physical activity that may be done every day without planning or taking time out of the day to be completed (i.e., walking up the stairs or running to catch a bus).

In recent years, immersive technologies such as virtual reality (VR) and augmented reality (AR) have slowly made their way to the frontier of patient care and health management. VR technology has been used in many hospitals to alleviate stress and anxiety and improve pain management by creating a digital environment that allows patients to interact safely with virtual characters and elements (Iqbal et al., 2024). In a study conducted in 2019, children aged 6-17 who were burn victims reported moderate to higher "worst pain" ratings during wound cleaning when they were given a "no VR" treatment compared to a "yes VR" one (Hoffman et al., 2019). Therefore, this research investigation will explore the effects of immersive technology on affective constructs as a means to improve the experience of lifestyle physical activity.

1.2 Hypotheses

The present investigation entails participation in lifestyle physical activity under four conditions. Three conditions include the use of augmented reality (i.e., encouragement, social, and gamification), plus a control (i.e., no technology) condition. We hypothesize that the gamification condition will facilitate the most positive affective valence, followed by the social, encouragement, and control conditions, respectively (H_1). We also predict that conditions involving augmented reality (i.e., encouragement, social, and gamification) will prompt higher arousal when compared to control (H_2). We hypothesize that the gamification condition will elicit the greatest attentional dissociation, followed by the social, encouragement, and control conditions, respectively (H_3). Finally, as an outcome-neutral test, we hypothesize that perceived exertion (H_4) will be statistically equivalent across conditions.

2 Method

2.1 Participants

Recruitment was facilitated through promotional flyers around UCL, word of mouth, and across social media platforms (e.g., LinkedIn and WeChat). Eligibility criteria ensured that participants were: (a) aged 18–45 years, (b) relatively sedentary (according to the Godin-Shephard Leisure-Time PA Questionnaire [scores ≥ 24] (Amireault et al., 2015)), (c) safe to engage in physical activity (according to the Physical Activity Readiness Questionnaire (PAR-Q; Warburton et al., 2011)), and (d) not easily susceptible to motion sickness (according to the Visually Induced Motion Sickness Susceptibility Questionnaire (VIMSSQ; Golding et al., 2021)). Twenty-four adult volunteers were recruited to facilitate a fully counterbalanced design ($M_{age} = 25.82$ years, $SD_{age} = 3.59$ years, $N_{female} = 10$, $M_{BMI} = 21.50$, $SD_{BMI} = 3.62$ kg/m^2).

2.2 Experimental Procedures

2.2.1 Baseline Assessment

The participant was invited to the ISEH lab for one session lasting 90 minutes. Upon arriving, the participant was asked to complete a demographic survey and the Preference for and Tolerability of the Intensity of Exercise Questionnaire (PRETIE-Q (Ekkekakis et al., 2008)). The baseline assessment allowed us to identify the target heart rate (THR), which was used in the Sub Maximal Exercise Test phase (see 2.2.3). THR was identified as 77% of the participant's maximum heart rate, which was calculated using Tanaka's formula: 208 - ($0.7 \times Age$) (Nikolaidis et al., 2018). We also recorded each participant's resting heart rate (RHR) using HRV Logger Pro.

2.2.2 Familiarisation

Participants were introduced to the four psychometric scales that were administered during the Main Experiment phase (see 2.2.4): Feeling scale (FS; (Hardy & Rejeski, 1989)), Felt arousal scale (FAS; (Svebak & Murgatroyd, 1985), Borg CR10 Scale (BS; (Gunnar, 1998), and Attention Scale (AS; (Tammen, 1996). Participants were then asked to step onto the treadmill and shown how to fit and adjust the augmented reality device. An application was loaded on the headset, which allowed participants to interact with digital assets with a controller and to practice walking on a treadmill with the headset.

2.2.3 Sub Maximal Exercise Test

The purpose of the submaximal exercise test was to determine an appropriate treadmill incline that was to be administered during the Main Experimental Phase (see 2.2.4). Each participant was required to fasten a Polar H9 heart rate sensor around their lower chest. Thereafter, the exercise test began at a 0% incline, and the treadmill speed (TS) was set at 3.5 mph and 3.8 mph for females and males, respectively. After 1 minute, the incline of the treadmill was increased to 2%. Subsequently, the incline was increased by 1% until the THR was achieved (see 2.2.1). The corresponding treadmill incline at THR was then designated as the target incline (TI). During the Sub Maximal Exercise test, the researchers practiced administering the four psychometric scales (i.e., FS, FAS, BS, AS) for familiarisation purposes and were not recorded.

2.2.4 Main Experiment Phase

This phase was split into three stages: (1) a 90-second warm-up (0-90s), (2) a main exercise phase (90s – 210s), and (3) a cool-down (210s – 240s). After the participant's heart rate returned to RHR, they stepped onto the treadmill at TI, where the scores of FS and FAS were recorded. The participant then put the headset on with the correctly loaded condition (i.e., encouragement, social, or gamification). When both the researcher and participant were ready, the respective TS for males and females were set (i.e., 3.5 mph or 3.8 mph), and the participant began the warm-up. During the main exercise stage, the FS, FAS, BS, and AS were recorded after 150s. After 210s, the cool-down stage began, where the incline of the treadmill was lowered to 50% of TI and the speed of the treadmill was slowed down to a stop at 240s. When the participant was stationary, the scores of FS and FAS were recorded for the third time. We employed a repeated measures experimental design, and therefore each participant was required to complete this process for all four conditions.

2.3 Measures

Affective valence was measured using the FS (Hardy & Rejeski, 1989), and arousal was measured using the FAS (Svebak & Murgatroyd, 1985), while perceptual measures were recorded using the Borg CR10 Scale (Gunnar, 1998) for ratings of perceived exertion (RPE) and the AS (Tammen, 1996) for state attentional focus. The FS is an 11-point scale ranging from -5 (*very bad*) to +5 (*very good*). The FAS is a 6-point scale ranging from 1 (*low arousal*) to 6 (*high arousal*). The Borg CR10 scale is a continuous scale ranging from 0 (*nothing at all*) to 11 (*extremely strong*). The AS is a continuous scale ranging from 0 (*internal focus – bodily sensations, breathing, heart rate, etc*) and 100 (*external focus – daydreaming, external* *environment, etc*).

3 Results

3.1 Core Affect

A repeated-measures ANOVA revealed a significant effect of condition on affective valence, $F(3,72) = 5.969,\ p = 0.00108$ (see Table 1). Pairwise comparisons indicated that both the gamification and social conditions elicited greater affective valence compared to the control condition (gamification: $p < .05$, social: $p < .01$) (see Table 2). The effect of condition on arousal was not statistically significant, $F(3,72) = 1.081,\ p = 0.363$ (see Table 1).

3.2 Perceptual Variables

For attentional dissociation, a repeated-measures ANOVA showed a significant effect of condition, $F(3,72) = 22.95,\ p = 1.57 \times 10^{-10}$ (see Table 1). Pairwise tests revealed that gamification and social conditions produced greater attentional dissociation than both control ($p < .001$) and encouragement (gamification: $p < .001$, social: $p < .05$), and that gamification exceeded social at $p < .05$ (see Table 2). The analysis of perceived exertion (RPE) indicated no significant effect of condition, $F(3,72) = 2.450,\ p = 0.0704$ (see Table 1).

Table 1: ANOVA Results for Affective Valence, Arousal, RPE, and Attention Scale

Dependent Variable	Source	Df	Sum Sq	Mean Sq	F value	$\Pr(>F)$
Affective Valence						
	Residuals (Within)	24	170.50	7.104	—	—
	Condition	3	14.44	4.813	5.969	0.00108 **
	Residuals (Between Conditions)	72	58.06	0.806	—	—
Arousal						
	Residuals (Within)	24	68.06	2.836	—	—
	Condition	3	1.95	0.650	1.081	0.363
	Residuals (Between Conditions)	72	43.30	0.6014	—	—
RPE						
	Residuals (Within)	24	95.96	3.998	—	—
	Condition	3	4.79	1.596	2.450	0.0704
	Residuals (Between Conditions)	72	46.90	0.6514	—	—
Attention Scale						
	Residuals (Within)	24	21243	885.10	—	—
	Condition	3	7641	2547.00	22.95	1.57×10^{-10} ***
	Residuals (Between Conditions)	72	7991	111.00	—	—

Table 2: Pairwise Comparisons (Bonferroni-adjusted) for Affective Valence and Attention Scale

	Affective Valence			
Comparison	Control	Encouragement	Gamification	Social
Encouragement	0.2574	—	—	—
Gamification	0.0273	0.4654	—	—
Social	0.0093	0.5142	1.0000	—
	Attention Scale			
Comparison	Control	Encouragement	Gamification	Social
Encouragement	1.00000	—	—	—
Gamification	5e-07	1e-05	—	—
Social	0.00037	0.03425	0.01431	—

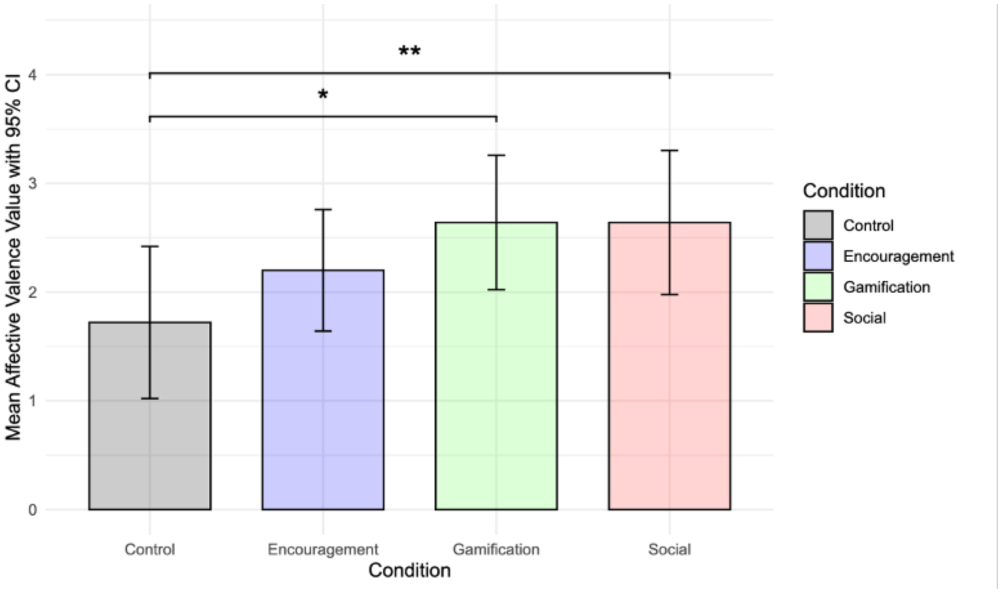

Figure 1: Mean Feeling Score Responses Across Conditions. Error Bars Denote 95% CIs.

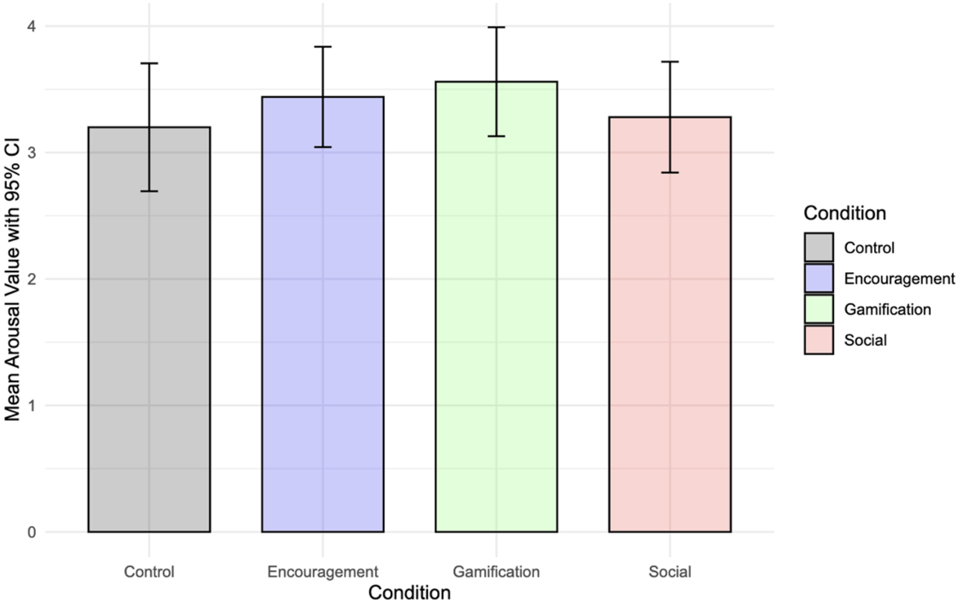

Figure 2: Mean Arousal Score Responses Across Conditions. Error Bars Denote 95% CIs.

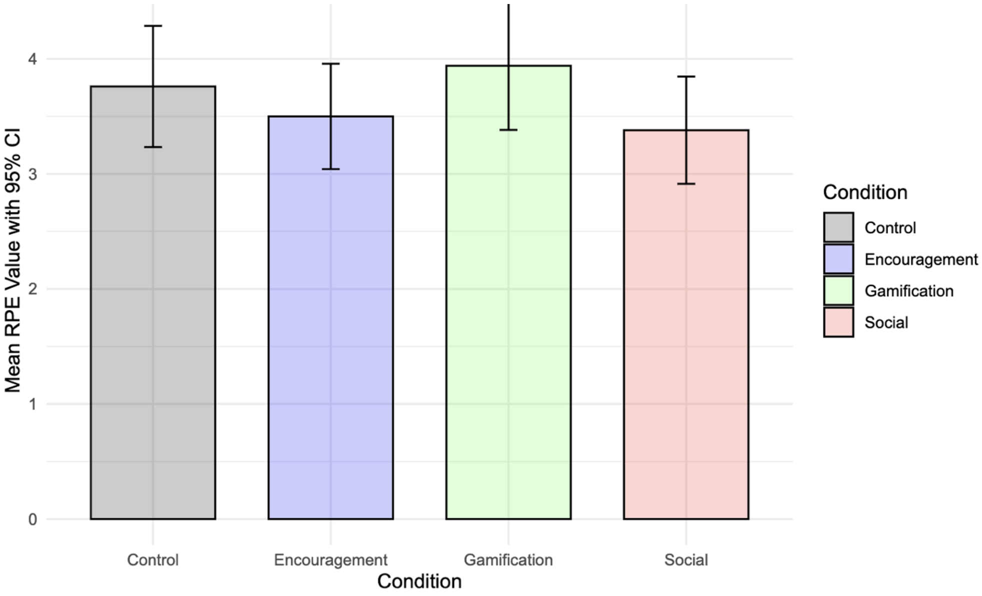

Figure 3: Mean RPE Score Responses Across Conditions. Error Bars Denote 95% CIs.

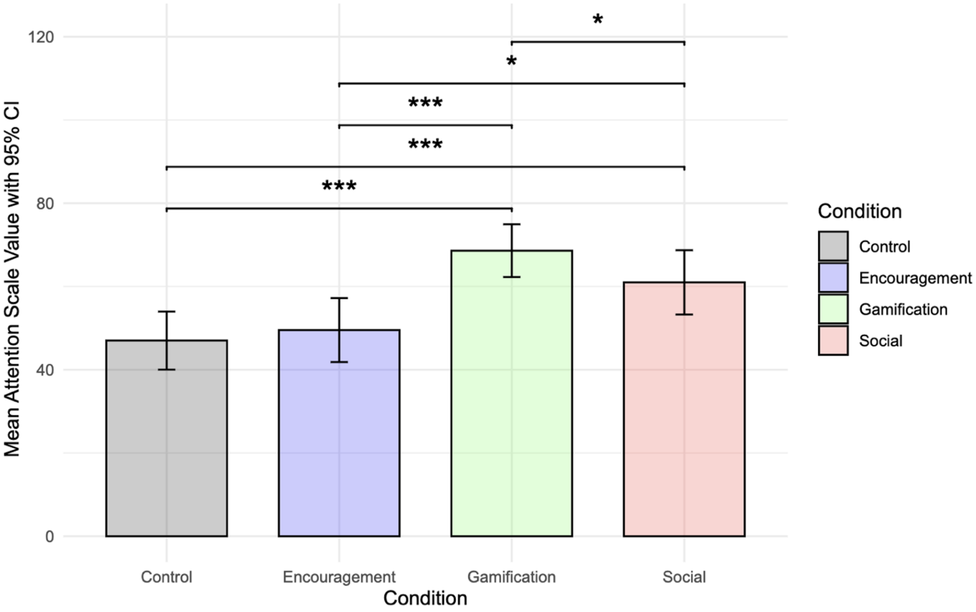

Figure 4: Mean Attention Scale Score Responses Across Conditions. Error Bars Denote 95% CIs.

4 Discussion

The purpose of the study was to examine the effects of augmented reality technology on affective and perceptual variables during lifestyle physical exercise between VT and RCP. Four research hypotheses were proposed, and results from the study led to the acceptance, non-acceptance, and partial acceptance of the hypotheses.

4.1 Core Affect

H_1 stated that the gamification, social, encouragement, and control conditions would elicit the greatest to least affective valence scores, respectively. This hypothesis is partially accepted, given that both the gamification condition and social conditions showed significantly higher affective valence scores than the control condition. However, the gamification and social conditions did not show higher affective valence scores than the encouragement condition, and there was no difference between the encouragement and control conditions (see Figure 1). H_2 predicted that conditions involving immersive technology would stimulate higher arousal compared to control. This hypothesis was not accepted because arousal scores did not differ significantly across conditions (see Figure 2) (p's $>$ .05).

The partial acceptance of H_1 suggests that while immersive technology has the possibility to enhance affective valence, the lack of difference between the encouragement and control conditions highlights the need to examine different forms of immersive technology and their individual effects on affective valence. Similarly, given the non-acceptance of H_2, it is plausible that participants may not have engaged with the immersive technology as strongly as predicted to cause significant arousal differences.

4.2 Perceptual Variables

H_3 held that attentional dissociation would be highest in the gamification condition, followed by social, encouragement, and control, respectively. As shown in Figure 3, there was a statistically significant difference in attentional dissociation across all four conditions (p's $<$ .001 and $p < .05$) apart from between the encouragement and control conditions ($p > .05$), therefore, H_3 is partially accepted. Finally, H_4 – the hypothesis for an outcome-neutral test – predicted no difference in RPE scores between conditions. This hypothesis is accepted, given that mean scores across all conditions were statistically non-significant ($p > .05$).

In relation to H_3, the significant differences in attentional dissociation across conditions suggest that augmented reality technology has the capacity to shift attention away from bodily sensations that are typically associated with fatigue during physical activity. This result aligns with previous investigations into the use of virtual reality technology in exercise. For example, (Bird et al., 2024) found similar results where specific conditions prompted higher state attention scores while RPE remained statistically equivalent, suggesting that between VT and RCP, high levels of engagement may change how attention is directed but have little effect on the perception of effort (Razon et al., 2009). The acceptance of H_4 meant that RPE scores were similar across conditions. Collectively, these results reveal that augmented reality technology can prompt more positive feeling states and greater attentional dissociation during lifestyle physical activity. However, participants' perception of exertion remained the same regardless of condition.

4.3 Strengths and Limitations

The concept of the study was derived from a conceptual framework used in past exercise psychology research studies and advancing previous work in the field (Ekkekakis, 2003; Ekkekakis et al., 2020). The investigation used the DMT to determine an exercise intensity that would be suitable for this experiment (between VT and RCP) and most likely to uncover meaningful effects. Moreover, we implemented a baseline assessment to identify resting and target heart rates for each individual, allowing for tailored exercise intensity and comparability across results. The repeated-measure design was also a strength of the study and reduced variability between participants and error variance.

Given that the research study was conducted in one 90-minute session, ecological variability is limited as responses in one laboratory bout cannot be generalised to longer exercise durations or real-world use of immersive technology (Heath, 2018). Furthermore, unfamiliarity with the headset, safety concerns, and discomfort (especially among novice users of immersive technology) may have influenced responses and confounded measurements despite the familiarization phase. The collection of each psychometric scale score was self-reported and may be interpreted differently for each participant, leading to observer or recall bias.

4.4 Implications and Future Directions

From this investigation, it is clear that technologies involving high engagement and interactivity, such as augmented reality, can improve affective valence and promote attentional dissociation during lifestyle physical activity. This form of physical activity provides a range of cardio-metabolic benefits given its potential to motivate and promote healthy lifestyle physiological habits (Santos et al., 2023). Future researchers who intend to design similar experiments should consider further examining ecological validity and whether these findings may hold in more natural contexts (i.e., at home). It may also be interesting to investigate the lack of difference between the encouragement and control conditions and their underlying psychological mechanisms, since the gamification and social conditions both elicited greater affective valence scores compared to the control. This would shed light on understanding what specific qualities of immersive technology may elicit the greatest positive feeling during moderately intense exercise.

5 Conclusions

We explored the effects of immersive technology on a range of variables —affective valence, arousal, attentional dissociation, and perceived exertion—during lifestyle physical activity between the VT and RCP. Grounded in the Dual Mode Theory (Ekkekakis, 2003; Ekkekakis et al., 2020), we tested four hypotheses comparing gamification, social interaction, encouragement, and control conditions. The findings indicate that the gamification and socially interactive conditions are effective in improving affective valence compared to the control (H1). It is also the case that attentional dissociation was highest in the gamification intervention, followed by social, while the encouragement and control conditions had no difference (H3). However, the arousal measures did not yield the results that were expected, and there was no difference across any conditions (H2). The outcome-neutral test (H4) showed no difference in RPE across conditions.

These results suggest that immersive technology interventions could be a promising route to improve the psychological experience of lifestyle physical activity, particularly by increasing positive feelings during the exercise and distracting attention away from internal discomfort. The limitations of the current work, such as laboratory settings, short session duration, and potential unfamiliarity with immersive environments, can be overcome, and future research should replicate these results in more ecologically valid settings. Given the widespread challenge of sedentary behaviour, such interventions will help bridge the gap between known health benefits of physical activity and the adoption of healthy physiological habits in daily life.

References

[1] Amireault, S., Godin, G., Lacombe, J., & Sabiston, C. M. (2015). The use of the Godin-Shephard Leisure-Time Physical Activity Questionnaire in oncology research: A systematic review. *BMC Medical Research Methodology*, 15, 60. https://doi.org/10.1186/s12874-015-0045-7

[2] Bird, J. M., Karageorghis, C. I., Jones, L., Harris, D. J., Alharbi, M., & Vine, S. J. (2024). Beyond Rubik: The Embodiment–Presence–Interactivity Cube applied to exercise. *Psychology of Sport and Exercise*, 74, 102684. https://doi.org/10.1016/j.psychsport.2024.102684

[3] Ekkekakis, P. (2003). Pleasure and displeasure from the body: Perspectives from exercise. *Cognition and Emotion*, 17(2), 213–239. https://doi.org/10.1080/02699930302292

[4] Ekkekakis, P., Hartman, M. E., & Ladwig, M. A. (2020). Affective Responses to Exercise. In G. Tenenbaum & R. C. Eklund (Eds.), *Handbook of Sport Psychology* (1st ed., pp. 231–253). Wiley. https://doi.org/10.1002/9781119568124.ch12

[5] Ekkekakis, P., Thome, J., Petruzzello, S. J., & Hall, E. E. (2008). The Preference for and Tolerance of the Intensity of Exercise Questionnaire: A psychometric evaluation among college women. *Journal of Sports Sciences*, 26(5), 499–510. https://doi.org/10.1080/02640410701624523

[6] Ekkekakis, P., Zenko, Z., & Vazou, S. (2021). Do you find exercise pleasant or unpleasant? The Affective Exercise Experiences (AFFEXX) questionnaire. *Psychology of Sport and Exercise*, 55, 101930. https://doi.org/10.1016/j.psychsport.2021.101930

[7] Golding, J. F., Rafiq, A., & Keshavarz, B. (2021). Predicting Individual Susceptibility to Visually Induced Motion Sickness by Questionnaire. *Frontiers in Virtual Reality*, 2, 576871. https://doi.org/10.3389/frvir.2021.576871

[8] Gunnar, B. (1998). Borg's perceived exertion and pain scales.

[9] Hardy, C. J., & Rejeski, W. J. (1989). Not What, but How One Feels: The Measurement of Affect during Exercise. *Journal of Sport and Exercise Psychology*, 11(3), 304–317. https://doi.org/10.1123/jsep.11.3.304

[10] Heath, W. (2018). *Psychology Research Methods: Connecting Research to Students' Lives* (1st ed.). Cambridge University Press. https://doi.org/10.1017/9781316105566

[11] Hoffman, H. G., Rodriguez, R. A., Gonzalez, M., Bernardy, M., Peña, R., Beck, W., Patterson, D. R., & Meyer, W. J. (2019). Immersive Virtual Reality as an Adjunctive Non-opioid Analgesic for Pre-dominantly Latin American Children With Large Severe Burn Wounds During Burn Wound Cleaning in the Intensive Care Unit: A Pilot Study. *Frontiers in Human Neuroscience*, 13, 262. https://doi.org/10.3389/fnhum.2019.00262

[12] Iqbal, A. I., Aamir, A., Hammad, A., Hafsa, H., Basit, A., Oduoye, M. O., Anis, M. W., Ahmed, S., Younus, M. I., & Jabeen, S. (2024). Immersive Technologies in Healthcare: An In-Depth Exploration of Virtual Reality and Augmented Reality in Enhancing Patient Care, Medical Education, and Training Paradigms. *Journal of Primary Care & Community Health*, 15, 21501319241293311. https://doi.org/10.1177/21501319241293311

[13] Nikolaidis, P. T., Rosemann, T., & Knechtle, B. (2018). Age-Predicted Maximal Heart Rate in Recreational Marathon Runners: A Cross-Sectional Study on Fox's and Tanaka's Equations. *Frontiers in Physiology*, 9, 226. https://doi.org/10.3389/fphys.2018.00226

[14] Razon, S., Basevitch, I., Land, W., Thompson, B., & Tenenbaum, G. (2009). Perception of exertion and attention allocation as a function of visual and auditory conditions. *Psychology of Sport and Exercise*, 10(6), 636–643. https://doi.org/10.1016/j.psychsport.2009.03.007

[15] Rhodes, R. E., & Kates, A. (2015). Can the Affective Response to Exercise Predict Future Motives and Physical Activity Behavior? A Systematic Review of Published Evidence. *Annals of Behavioral Medicine*, 49(5), 715–731. https://doi.org/10.1007/s12160-015-9704-5

[16] Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology*, 39(6), 1161–1178. https://doi.org/10.1037/h0077714

[17] Santos, A. C., Willumsen, J., Meheus, F., Ilbawi, A., & Bull, F. C. (2023). The cost of inaction on physical inactivity to public health-care systems: A population-attributable fraction analysis. *The Lancet Global Health*, 11(1), e32–e39. https://doi.org/10.1016/S2214-109X(22)00464-8

[18] Schultchen, D., Reichenberger, J., Mittl, T., Weh, T. R. M., Smyth, J. M., Blechert, J., & Pollatos, O. (2019). Bidirectional relationship of stress and affect with physical activity and healthy eating. *British Journal of Health Psychology*, 24(2), 315–333. https://doi.org/10.1111/bjhp.12355

[19] Svebak, S., & Murgatroyd, S. (1985). Metamotivational dominance: A multimethod validation of reversal theory constructs. *Journal of Personality and Social Psychology*, 48(1), 107–116. https://doi.org/10.1037/0022-3514.48.1.107

[20] Tammen, V. V. (1996). Elite middle and long distance runners associative/dissociative coping. *Journal of Applied Sport Psychology*, 8(1), 1–8. https://doi.org/10.1080/10413209608406304

[21] Warburton, D. E. R., Jamnik, V. K., Bredin, S. S. D., McKenzie, D. C., Stone, J., Shephard, R. J., & Gledhill, N. (2011). Evidence-based risk assessment and recommendations for physical activity clearance: An introduction. *Applied Physiology, Nutrition, and Metabolism*, 36(S1), S1-S2. https://doi.org/10.1139/h11-060

Reflections on What I Learned

As a student fortunate enough to be given this opportunity to experience research first-hand, there are a few lessons that I have learnt and will take away with me.

Though it has been said many times, communication is a necessary skill in the world of research. Whether it is with participants, my supervisor, or other co-workers, communicating on a Teams call or a simple text can be important in keeping the team on the same page. I have further noticed that effective communication is particularly important when dealing with participants to ensure that they are well versed with the procedures of the experiment. If not done correctly, the participant can be left confused, which may affect the quality of the collected data or waste the participant's time by repeating procedures. Often, as a lead researcher or even as a research assistant, you are your own boss in the sense that the speed at which you can complete an experiment depends exactly on the effectiveness of your own work. Working times when doing research also fluctuate often. There could be times when I have 5 participants coming in, keeping me in the lab from 9:00 – 18:00, or days when there is only 1 participant. I learnt that staying disciplined and trying to make the most out of each day can not only improve my productivity overall, but also save time by working on multiple 'things' during a working day. Finally, I have also learnt what it is like to be a researcher. From sitting behind a computer sorting and cleaning through data to talking to multiple participants a day, being a researcher requires a wide range of skills. You need to be innovative to think of new experiments, while also having to adapt and make changes to improve procedures.