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Comparing the play of sport and action-adventure game genres on heart rate and heart rate variability

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ABSTRACT

The ability to cope with stress is imperative for performance in competitive gaming, yet there is a lack of research examining the impact of gaming and esports participation on physiological stress. One way to measure physiological stress is via heart rate variability (HRV). The current literature examining HRV during competitive gaming is limited, with most studies focusing on multiplayer online battle arena games. To better understand the physiological demands of gaming, investigation into the stress imposed on players during gameplay of various game genres is required. In this study, we compared the physiological stress incurred on players who played either a competitive (sports) or a non-competitive (action-adventure) video game. Forty participants played either a sports or action-adventure game, whilst having their heart rate and heart rate variability monitored. Results showed that, compared to a pre-gaming baseline, playing either game increased heart rate, lowered RR intervals, and reduced both vagally mediated time and frequency domain vmHRV. Playing the sport game for 10 min induced higher heart rate and lower RR intervals compared to playing the action-adventure game. However, 10 min of game play was not enough to identify meaningful differences in vmHRV based on game genre played. These findings advance our understanding of the impact of video gaming on heart rate and heart rate variability, providing a useful method for coaches and players to index player stress and recovery.

1. Introduction

Video games are ubiquitous within modern society. Engagement with organised competitive professional video gaming, known as esports (Campbell et al., 2018), is also rising. This multi-billion-dollar industry offers large prize pools for competitors and now rivals, and often exceeds, the viewership of many traditional sports (Cranmer et al., 2021). The surge in popularity of gaming and esports has brought with it an increased interest to better understand the determinants of esports performance. While machine learning (Smithies et al., 2021), artificial intelligence (Hojaji et al., 2024), and data analytics models (Novak et al., 2020) have been used to identify in-game or mechanical performance metrics investigating the human factors that are related to gaming performance are also of great scientific interest.

Gaming places unique demands on cognitive skills, with Toth and colleagues (2020) highlighting the importance of information processing, task switching, attention and memory abilities for optimal gaming

performance. Researchers are starting to explore the impact of psychological factors on performance, investigating areas such as psychological skill use (Himmelstein et al., 2017), mental toughness (Poulus et al., 2020), coping strategies (Smith et al., 2019; Poulus et al., 2022) self-regulation (Trotter et al., 2023), and psychophysiological stress (Leis & Lautenbach, 2020). The ability to cope with stress is imperative for successful gaming performance, yet there is limited research examining physiological stress in esports. In a systematic review by Leis and Lautenbach (2020) examining both psychological and physiological stress in non-competitive and competitive esports settings, the researchers suggest that conclusions pertaining to physiological stress in esports are mixed based on available evidence and highlight an urgent need for more research into the role of physiological stress in competitive gaming.

When examining the potential effect of physiological stress on gaming performance, it is important to consider Yerkes-Dodson's law (1908), which posits that a moderate amount of physiological arousal is

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required for optimal performance. This theory suggests that too little physiological arousal results in boredom and hinders performance while excessive arousal also negatively impacts performance (Yerkes & Dodson, 1908). Research by Hardy and Parfitt (1991) in traditional sport supports this assertion, finding that the performance of basketball players is greatest in states of low to moderate physiological arousal. This is also supported by early work in gaming research, with Schmidt et al. (2020) demonstrating that performance is highest in individuals with low to moderate physiological stress compared to those experiencing high physiological stress. By recognising the potential for excessive physiological arousal to negatively impacting performance, it becomes clear that a better understanding of the physiological demands of esports is necessary.

One way to examine physiological stress is via heart rate variability. Heart rate variability (HRV) relates to the measure of the variation in time intervals between consecutive heartbeats (McCarty & Shaffer, 2015) and is an ideal marker of physiological stress as it provides information regarding the interplay between the sympathetic (fight or flight system) and parasympathetic (rest and digest) branches of the autonomic nervous system (Peabody et al., 2023; Immanuel et al., 2023). HRV is recognised by both The Task Force of the European Society of Cardiology (ESC) and the North American Society of Pacing and Electrophysiology (NASPE) as a biological marker of physiological stress (Peabody et al., 2023) and is further supported by neurobiological evidence (Kim et al., 2018) as a valid, reliable, and more sensitive marker of stress than heart rate alone (Peabody et al., 2023). During the experience of stress, the sympathetic branch of the nervous system, enables us to respond to the stressor by increasing heart rate, blood pressure and respiratory rate. Once the stressor dissipates, parasympathetic activity increases to balance physiological response and achieve homeostasis. As movement can influence the autonomic nervous system (Brodal, 2010), the sedentary nature of gaming lends well to examining stress-related HRV (Ketelhut et al., 2021). Mosley and Laborde (2022) suggest vagally mediated heart rate variability (vmHRV) reflects physiological stress. VmHRV measures include the root mean square of successive differences in heartbeats (RMSSD), the primary time-domain measure of vmHRV (Shaffer & Ginsberg, 2017), and the absolute power of the high frequency (HF ms^2), a frequency domain metric of vmHRV. HF ms^2 measures parasympathetic activity (Kim et al., 2018), and is positively correlated with RMSSD (Laborde et al., 2017). Reduced HF ms^2 and reduced RMSSD indicate greater physiological stress.

The deficiency in the field of video gaming and esports that this work addresses is that whilst emotion regulation and stress are important topics of study in relation to performance (LeBlanc, 2009; Wagstaff, 2014), little work has been done examining how stress manifests among players who play different types of video games, relative to other areas of research. A recent systematic review examining HRV in esports (Welsh et al., 2023) identified only 7 studies examining physiological stress via HRV in esports, from which the evidence is mixed. Andre et al. (2020) examined the physiological impact of esports competition on players using heart rate and heart rate variability, finding heart rate to increase during competition compared to pre-competition. However, these same authors found no difference in vmHRV (RMSSD & HF ms^2) at any time point. Machado et al. (2022) also examined the physiological impact of esports, specifically the role of victory and defeat in esports on HRV, finding that post game, the victory group to have both lower self-reported stress, and lower HRV-related stress (reflected in increases standard deviation of NN intervals (SDNN), percentage of successive RR intervals that differ by more than 50 m (pNN50), RMSSD, & HF (ms^2)) compared to the defeat group.

Watanabe et al. (2021) also examined the impact of competitive play on heart rate, by comparing a player vs player (PvP) condition to player vs computer (PvC), finding heart rate to be elevated in the more competitive (PvP) condition and suggest that the sympathetic nervous system was activated by the magnitude of the competition. Ketelhut & Nigg (2024) also found that playing competitive video games elicits a

physiological stress response, evidenced in increased heart rate, blood pressure and reduced HRV. However, they found no differences between players competing in sports and MOBA games. A plausible explanation for Ketelhut & Nigg, (2024) not finding differences between these game genres could be attributed to the fact that they are both highly competitive game genres, with Ketelhut & Nigg (2024) acknowledging the possibility that the elevated physiological stress they observed in both games could be related to the competitive nature of the game rather than the specific game title.

Whilst the aforementioned studies focused on competitive gaming, there is currently a lack of research examining how competitive genres compare to non-competitive genres regarding their impact on physiological stress. Watanabe et al. (2021) suggest that physiological stress responses during video game play may depend on the degree to which competition is encouraged, highlighting the need to explore differences in physiological stress in competitive vs non-competitive game genres, an area of research which is largely unexplored. In recent work by Cregan et al., (2024) researchers found those playing sports games were the most motivated to play for competitive reasons and those playing action-adventure games the least motivated to play for competitive reasons.

Based on these findings, the purpose of the current study is to compare the physiological stress responses of gamers playing a competitive esports (sports game) to a traditionally non-competitive (action-adventure game) video game. Given the recognition that playing video games can increase heart rate and decrease HRV (Ketelhut & Nigg, 2023), we first hypothesise that playing either game will cause an increase in physiological responses among players compared to baseline rest period, evidenced by an increase in heart rate and decrease in RR intervals among players of both game genres. Secondly, we hypothesise that playing either game will cause an increase in objective physiological stress via vmHRV, specifically by observing decreases in both high frequency power and RMSSD. Fuentes-Garcia et al., (2019) suggest that incorporating subjective perceptions of stress can help reinforce HRV information and aid in the interpretation of psychophysiological data. For this reason, subjective physiological stress will also be examined via self-report stress questionnaires. We hypothesise thirdly that playing either game will increase subjective physiological stress, as measured using a self-reported stress scale. Fourthly, given the role of competition in increasing sympathetic activity (Watanabe et al., 2021), we hypothesise that playing a sports game will cause a greater increase in physiological response compared to playing the action-adventure game. This will be evidenced by observing increased heart rate and decreased RR intervals. We also hypothesise that playing the sports game will result in a greater increase in objective physiological stress compared to playing an action-adventure game. This will be evidenced by observing a greater decrease in high frequency power and RMSSD among sports game players compared to action-adventure players. Finally, based on the aforementioned research, we also hypothesise is that playing a sports game will cause a greater increase in subjective physiological stress compared to playing the action-adventure game.

2. Methods

2.1. Participants

Forty ($N = 40$; 35 males, 5 females) participants (age 24.30 ± 6.82 years (mean \pm SD)) were recruited for our study at the Gamescom gaming convention, in Cologne, Germany. Testing took place in a booth, whereby the participants sat in a quiet area at an individual gaming set up, without visual distractions and with headphones to eliminate any auditory distractions. The sports and action-adventure games chosen for the study were FIFA 23 and Assassin's Creed Valhalla respectively. All participants were required to be familiar with and have had experience with playing the video game of choice. Of the sample, 22 were allocated to playing the action-adventure game and 18 were allocated to the

sports game.

A sample size of $N = 36$ was estimated according to an a priori G^* Power calculation v3.1.9.7 (Faul et al., 2007). A large effect size was used based on a study of similar design by Machado et al. (2022). The alpha level was set at .05, power to .80, and a correlation of .5 was used. Participants who were over 18 years of age, with no cardiovascular disease were eligible to participate in the study. This study was approved by the University of Limerick Faculty of Education and Health Sciences Research Ethics Committee in the University of Limerick [2023.06.17.EHS] in accordance with the Declaration of Helsinki. Participants were provided with information regarding study details and were requested to provide their informed consent prior to participation.

2.2. Questionnaires

Given that factors such as mood (Moreno et al., 2013), emotion regulation style (Appelhans & Luecken, 2006), stress appraisal (Porter & Goolkasian, 2019) and sleep quality (Bourdillon et al., 2021) can impact HRV, these potential confounding variables were measured via the following questionnaires.

2.3. Brunel mood scale

The Brunel Mood Scale (BRUMS) (Terry et al., 1999) was included to measure mood state. This scale has been demonstrated to be a reliable and valid measure of mood, measuring anger, vigour, fatigue, tension, depression, and confusion. Responses were rated using a five-point Likert scale, whereby 0 = not at all, 4 = extremely.

2.4. Emotion regulation questionnaire

The emotion regulation questionnaire (Gross & John, 2003) measures tendency to regulate emotions by engaging in (i) cognitive reappraisal (6 items) and (ii) emotion suppression (4 items). The scale has been shown to be both valid and reliable (Gross & John, 2003) and requires participants to respond to statements using a 7-point Likert scale, whereby 1 = strongly disagree, and 7 = strongly agree.

2.5. Stress appraisal scale

These scales, based on the biopsychosocial model of challenge and threat (Tomaka et al., 1993) were created by Porter and Goolkasian (2019) and addresses perception of a task as being challenging or threatening. Higher scores on the primary appraisal scale indicate higher threat appraisal. Contrastingly, higher scores of secondary appraisal scale indicate higher challenge appraisal of the task.

2.6. Single-Item Sleep Quality Scale

The single item sleep quality scale (Snyder et al., 2018) measures quality of sleep over a 7-day period on a scale of 0–10. These scores then fit one of five categories, specifically, 0 = terrible, 1–3 = poor, 4–6 = fair, 7–9 = good, or 10 = excellent sleep quality. This scale has demonstrated to be a reliable and valid measure of sleep quality (Snyder et al., 2018).

2.7. Subjective self-reported stress

Participants were then asked to report their subjective stress levels using a 10-point Likert scale.

3. Materials

3.1. Video Games

As mentioned previously, we compared the physiological responses

of participants playing an action-adventure game to a sports game. All participants played the video games using a gaming laptop (Lenovo Legion S5) and 27-inch monitor (Samsung C27G75 Odyssey, 272, 144 Hz refresh rate). Participants were instructed to play as normal and were given the option of using a Logitech pro wireless mouse and pro keyboard to game, or to use a Dual Shock 4, or Xbox Elite Controller (series 2).

3.2. Physiological responses

To investigate the effect of game play on physiological response, participants heart rate and HRV were measured using Polar v800 heart rate sensor and Polar H10 chest strap, which has been demonstrated to be a valid and reliable measures of RR intervals and HRV (Speer et al., 2020) sampling at a rate of 1 Hz.

3.3. Baseline video

Participants watched an aquatic video for 5 min during which a baseline recording of their heart rate and heart rate variability was obtained. The choice of baseline video was based on suggestions by Laborde et al. (2017), who recommend utilising neutral stimuli such as aquatic videos to help standardise and reduce mind wandering during acquisition of baseline cardiac recordings. The duration of the baseline video was 5 min based on recommendations by Task Force of the European Society of Cardiology and the North American Society of Pacing Electrophysiology (1996).

3.4. Protocol

Participants were provided with the Polar v800 watch and Polar chest strap and instructed to secure the polar chest strap across their chest, in direct contact with skin. They were provided with a photo from the Polar manual demonstrating the correct placement of the monitor to assist them in securing the chest strap. Participants were then asked to complete the questionnaires (demographics, BRUMS, ERQ, and Sleep Quality Scale) and report their subjective stress levels at using a 10-point Likert scale (baseline subjective stress). Participants were then instructed to watch the baseline video for a duration of 5 min to obtain resting heart metrics. In line with guidelines provided by Laborde et al., (2017) participants were instructed to relax, avoiding both movement and speaking, while watching the baseline video. Participants were then asked to report their subjective stress levels again. Participants were then asked to report their motivation to play the upcoming game (on a 10-point Likert scale) and complete a stress appraisal scale in relation to the upcoming game. As participant skill level varied, the difficulty setting was customized based on the skill level reported by the individual player. To determine this, consideration was given to how many years the individual played and what difficulty setting they most commonly play on (for example semi-professional, professional, world class and legendary) or for the action-adventure game (easy, default, hard etc). Participants were then given instructions to play the game to the best of their ability for 10 min, while cardiovascular metrics were monitored. Both games were played in single mode and players played against artificial intelligence (AI)-based bots. After 10 min of game play, the participants then rated their subjective stress levels for the final time. A flow chart of the methodology is available in [Supplementary File 1](#).

3.5. Data processing

RR intervals were processed in 5-min epochs (baseline, 0–5 min gameplay, 5–10 min gameplay) using a custom-built LabVIEW programme. RR intervals 2 SD outside a participant's individual results for their baseline or in game data were removed. Average heart rate was then calculated by dividing each RR value by 60 and averaging the resulting values within each 5-min epoch (baseline, 0–5 min of game

play and 5–10 min of game play). To obtain participants mean RR score, equation (1) was computed (Task Force Report, 1996).

$$\overline{RR} = \frac{1}{N} \sum_{n=1}^N RR_n \quad (1)$$

To calculate the RMSSD, RR intervals were converted from seconds to milliseconds, then the difference between intervals was squared, averaged and square rooted as seen in equation (2) (Task Force Report, 1996).

$$RMSSD = \sqrt{\frac{1}{N-1} \sum_{n=1}^{N-1} (RR_{n+1} - RR_n)^2} \quad (2)$$

To obtain the high frequency domain metrics from the RR intervals, Kubios HRV software (v 3.5) was used. A Fast Fourier transform was performed on the RR interval data and the absolute power within the high frequency band (HF), between .15 and .4 Hz, was calculated by ms²/Hz.

3.6. Data analyses

Data analyses were performed using SPSS version 28. Normality of data residuals was determined by observing Shapiro-Wilk statistics and examining histograms. Based on consideration of the Shapiro-Wilk statistics and box plots, three participants were excluded for subsequent analysis as their data exceeded 1.5 times the inter quartile range, leaving (N = 37) participants, (N = 20) action-adventure players and (N = 17) sport players. The distribution of high frequency scores was right skewed and as a result, these data were natural logarithm transformed prior to parametric analysis. ERQ, BRUMS, stress appraisal scale, single item sleep scale and motivation scale scores were computed for each participant. T-tests were then completed to determine if there were any differences in mood, emotion regulation style, stress appraisal, sleep quality and motivation between sport and action-adventure players at baseline to control for these variables as potential confounds.

To address our first hypothesis, that playing either game would increase physiological response, we conducted a one-way (Time Point) MANOVA on Heart Rate and Mean RR scores. To address our second hypothesis, that playing either game would increase objective physiological stress compared to baseline, we completed a one-way (Time Point) MANOVA on High Frequency power and RMSSD scores. To address our third hypothesis, that playing either game would increase subjective stress compared to baseline, we conducted a one-way (Time Point) ANOVA on self-reported stress scores. To address our fourth hypothesis that playing a sports game would cause a greater increase in physiological response compared to the action adventure, we conducted a two-way (Game Genre x Time Point) MANCOVA (Heart rate & Mean RR scores). As heart rate and RR scores differed between game groups at baseline, baseline scores for both variables were included as covariates in the model. To address our fifth hypothesis that playing a sports game would result in a greater increase in objective physiological stress compared to playing an action-adventure game, we completed a two-way (Group x Time Point) MANOVA (High Frequency power & RMSSD). To address the final hypothesis, that playing a sports game would cause a greater increase in subjective physiological stress compared to playing the action-adventure game, we performed a two-way ANCOVA (Group x Time Point) on self-reported stress scores. Where the assumption of Mauchly's test of sphericity was violated, a Greenhouse-Geisser correction was applied. Sidak alpha corrections were applied to account instances of multiple comparisons. Results are reported as means ± SE with a significance alpha level of p < .05.

4. Results

Results from the t-tests comparing sport and action adventure

players in emotion regulation strategies (ERQ scores), mood (BRUMS scores), stress appraisal (Stress Appraisal Scale), sleep quality (single item sleep scale), and motivation (motivation scale) revealed no significant differences between sports and action-adventure players (Supplementary File Table 1).

Regarding our first hypothesis, there was a significant main effect of time point on the combined dependent variables (F(4, 33) = 2.695, p = .048; Wilks' Λ = .754, partial η^2 = .246) with significant effects for both heart rate (F(1.471, 52.942) = 6.227, p = .008) and mean RR interval (F(1.453, 52.315) = 8.177, p = .002) (Fig. 1). Heart rate was significantly higher during 0–5 min of game play (p = .047) and 5–10 min of game play (p = .027) compared to baseline but not different between 0 and 5 min of game play and 5–10 min of game play (p = .332) (Fig. 1a). Mean RR was significantly lower following both 0–5 min of game play (p = .016) and 5–10 min of game play (p = .009) compared to baseline but not between 0–5 and 5–10 min of game play (p = .182) (Fig. 1b).

Regarding our second hypothesis, there was a significant main effect of time point for the combined dependent variables (F(4,33) = 2.703, p < .001; Wilks' Λ = .553, partial η^2 = .447) with significant effects for both high frequency power (F(1.308, 47.096) = 16.026, p < .001, η^2 = .308) and RMSSD (F(1.317, 47.401) = 16.027, p < .001, η^2 = .309) (Fig. 1). Post hoc comparisons showed a significant decrease in HF ms² during 0–5 min of game play (p < .001) and 5–10 min of game play (p < .001) compared to baseline with no significant difference between 0 and 5 min of game play and 5–10 min of game play (p = .998). RMSSD also significantly decreased from both 0–5 min of game play (p = .003) and 5–10 min of game play (p < .001) compared to baseline, with no significant difference between 0 and 5 min of game play to 5–10 min of game play (p = .356).

In line with hypothesis three, we found a significant main effect of time point on self-reported stress, F(2, 35) = 43.836, p < .001, Wilks' Λ = .258, partial η^2 = .715. Stress levels were significantly higher at the beginning of the study, prior to watching the video, compared to stress levels after watching the 5-min video (p < .001). Stress levels were significantly higher after 10 min of game play compared to the beginning of the study (p = .001). Stress levels were also significantly higher after 10 min of game play compared to watching the video (p < .001).

When comparing the magnitude of change in HR and RR between game groups, we found a significant main effect of group on the combined dependent variables after controlling for baseline scores (F(2, 32) = 4.866, p = .014; Wilks' Λ = .767, partial η^2 = .233) (Fig. 1). However, there was no significant main effect of time point (F(2, 32) = 2.703, p = .087; Wilks' Λ = .855, partial η^2 = .145), nor a Time Point x Game Group interaction (F(1, 34) = 3.184, p = .083; Wilks' Λ = .914, partial η^2 = .086).

Considering the suggestion of Wanantabe et al., (2021) and Ketelhut & Nigg, (2024) that physiological stress responses during video game play may depend on the degree to which competition is encouraged, paired with findings from Cregan et al., (2024) highlighting that sports game players were 29% more likely to play for competitive reasons than action adventure players, we examined the simple effects comparing the change in HR and RR from baseline to 0–5 min and 5–10 min of gameplay between gaming groups according to hypothesis 4. Heart rate was significantly more elevated amongst those playing the sports game compared to those playing the action adventure game during both 0–5 (p = .005) and 5–10 min of game play (p = .031). Moreover, mean RR was significantly lower amongst those playing the sports game compared to those playing the action adventure game during both 0–5 (p = .004) and 5–10 min game play (p = .015).

Regarding the fifth hypothesis when examining HRV variables, there was a significant main effect of time point on the combined dependent variables (F(4, 32) = 6.430, p < .001; Wilks' Λ = .554, partial η^2 = .446). There was no significant effect of group on the combined dependent variables (F(2, 34) = 2.533, p = .094; Wilks' Λ = .870, partial η^2 = .130) nor was there a significant interaction of Time Point x Group (F(4, 32) = .298, p = .877; Wilks' Λ = .964, partial η^2 = .036). In line with our fifth

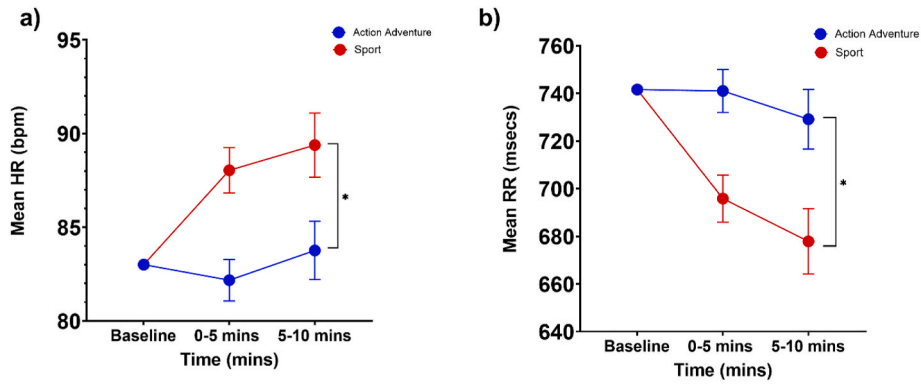


Fig. 1. (a) Mean HR based on groups at baseline, 0–5 min of play and 5–10 min of play. (b) Mean RR based on groups at baseline, 0–5 min of play and 5–10 min of play. * denotes significance at ($p < .05$).

hypothesis, simple effects comparing RMSSD and HF ms^2 between gaming groups at baseline, 0–5 min and 5–10 min of gameplay revealed no differences between groups at baseline ($p = .150$), but showed that sport players demonstrated significantly lower HF ms^2 scores compared to those playing the action adventure game during both 0–5 ($p = .018$) and 5–10 min game play ($p = .037$) (Fig. 2a). RMSSD did not differ between groups at any time point (Fig. 2b).

Regarding our final hypothesis, after controlling for self reported stress at the beginning of the study, there was a significant main effect for time on self reported stress, $F(1, 34) = 34.771, p < .001$; Wilks' $\Lambda = .494$, partial $\eta^2 = .506$ (Fig. 3). There was no significant interaction of Time x Group, $F(1, 34) = 3.184, p = .083$; Wilks' $\Lambda = .914$, partial $\eta^2 = .086$.

5. Discussion

This study set out to examine the impact of playing video games on physiological stress and determine if the game genres differed in physiological response according to the degree competition was encouraged. We found that relative to watching a baseline video, playing either game increased physiological response via increased heart rate and decreased RR intervals, time and frequency domain vagally mediated HRV.

Watanabe et al. (2021) suggest that increased HR and reduced HRV during game play, reflects activation of the sympathetic nervous system and may function to boost cognitive abilities over the short term to aid performance. Previous studies suggest that sympathetic activation of the nervous system can occur in response to cognitive demand, with higher HR and lower HRV during performance reflecting increased cognitive load, mental effort and task engagement (Mukherjee et al., 2011; de Manzano et al., 2010). By way of example, Fuentes-Garcia et al., (2019)

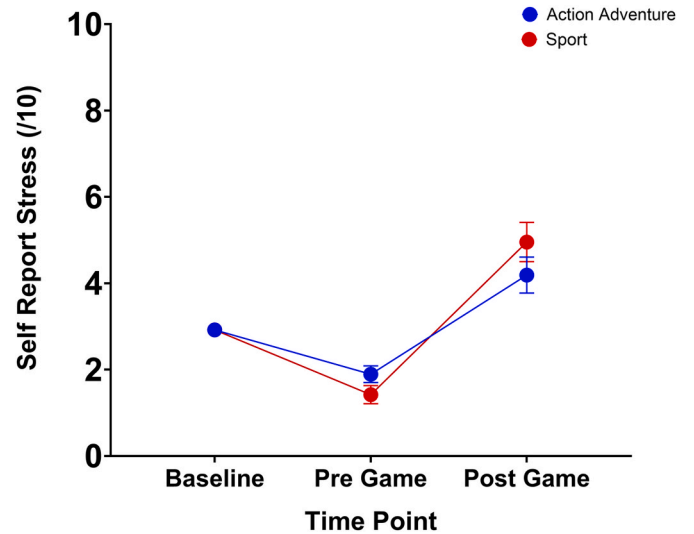


Fig. 3. Self Reported stress scores based on genre, at 3 different time points (beginning of study (pre-baseline), after watching aquatic video (post-baseline), and after game play (post game)).

found playing chess matches to reduce HRV, noting that as task difficulty intensified, HRV continued to decrease, offering a potential explanation as to why there was a significant increase in heart rate and reduction in HRV, relative to baseline.

The changes in heart rate and HRV observed in our study, fit within a similar range to what has previously been noted in esports research

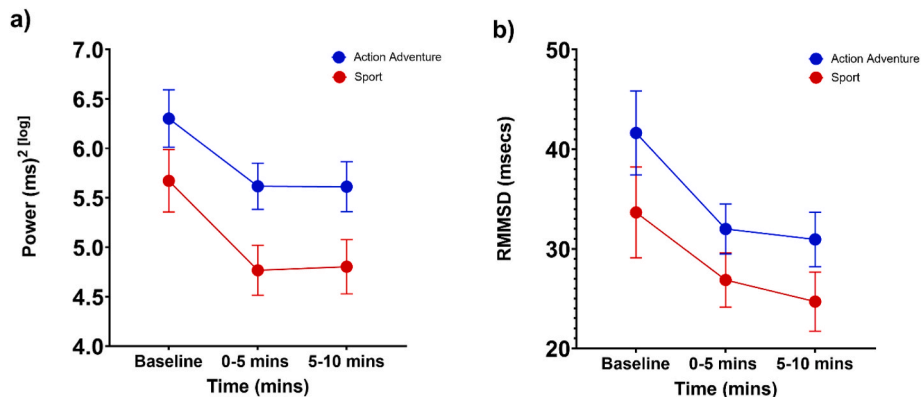


Fig. 2. (a) Natural logarithm transformed values of High Frequency Power ms^2 based on groups at baseline, 0–5 min of play and 5–10 min of play. (b) RMSSD (msecs) based on groups at baseline, 0–5 min of play and 5–10 min of play.

(Ketelhut & Nigg, 2024; Behnke et al., 2024). Yeo et al. (2017) also found engagement in competitive gaming to significantly increase heart rate. However, of notable interest is that heart rate in our study was lower than levels reported in live esports tournaments (Andre et al., 2020), highlighting the potential increased impact live competitions and performance pressure has in impacting heart rate. This is also supported by participants self-reported stress in our study. Whilst subjective stress significantly increased, participants reported a mean subjective stress score of 4.5 on a scale ranging from 0 to 10, indicative that they weren't excessively stressed because of game play.

Contrastingly, Zimmer and colleagues (2022) found no significant difference in heart rate when comparing playing Fifa to CSGO, nor did Siervo and colleagues (2018) when comparing violent and non-violent video games, specifically, Fifa to Call of Duty. Siervo et al. (2018), did however, find significant differences in heart rate when comparing either game to watching non-violent television. These findings highlight the possibility that it was perhaps the competitive nature of the video game impacting heart rate. This suggestion is supported by the work of Adachi and Willoughby (2011) who found that when game difficulty and pace of action are considered, competitive games rather than violent ones had a greater impact on physiological response. As the studies of Andre et al. (2020), Yeo et al. (2017) and Siervo et al. (2018) focus on competitive games, the current study advances the available research, comparing a competitive game centred upon winning to an action-adventure game focused on an immersive storyline (Pallavicini et al., 2022).

We also identified reduced vagally mediated HRV as a result of game play. The high frequency band measures parasympathetic activity (Kim et al., 2018), providing an important marker of physiological stress, with lower high frequency power correlated with stress, panic, worry and anxiety (Shaffer & Ginsberg, 2017). In a study by Andre et al. (2020) examining esports tournaments, the researchers didn't find competing in esports to impact time domain HRV, but they did find it to impact frequency domain HRV. In traditional sport, researchers have found reduced high frequency power to be associated with competitive stress (Sartor et al., 2017) and elevated anxiety during competition (Cervantes Blasquez et al., 2009). Mosley and Laborde (2022) offer a potential explanation for this, suggesting that athletes with higher levels of anxiety, are less able to effectively self-regulate during competition, as attention is attributed to the demanding situation, reducing the availability of resources to effectively regulate emotions, reducing vmHRV.

Our results suggest that playing the sport game may have induced a greater reduction in vagally mediated high frequency ms^2 , indicative that more competitive game genres may induce higher physiological stress. However, due to only collecting 10 min of game play, we note that there more meaningful differences may have emerged with longer game play periods. Another potential explanation for this could be attributed to the fact that at times, there were still some elements of competition (via combat) in the action-adventure game. For this reason, future research would benefit from examining the impact of gaming on HRV and heart rate over a longer period, and across a greater variety of game types. Another potential reason could be attributed to the fact that we looked at linear metrics of HRV. In Fuentes-Garcia et al., (2019) work, researchers found nonlinear HRV indexes to be more reactive to tasks difficulty than linear HRV indexes, so future research may also benefit from also examining these alternative metrics.

A limitation of this study is that we included one physiological measure of stress, specifically heart rate variability. Future research would benefit from examining additional markers of stress to help triangulate the findings, for example, using brain imaging techniques such as fNIRS to further examine stress and emotion regulation in performance. Additionally, whilst both games take place in 3D environments and both require the gamer to control an avatar, we acknowledge the difficulty with fully controlling the game conditions, given the dynamic nature of gaming environments. Whilst this adds to the ecological validity, future research would benefit from examining game play across

a longer period of time and including a wider variation of game genres and gaming environments.

The results of this study have implications for optimising player performance, with HRV providing an important index of player stress, and recovery, providing a cost-effective tool for players and coaches to monitor training load. The findings also demonstrate the potential utility of incorporating technology such as biofeedback in training to make players more aware of their physiological arousal, with studies demonstrating how biofeedback can be used to regulate emotions and improve performance (Jerčić & Sundstedt, 2019). Further research is needed to better understand the degree to which different game genres impact physiological stress. Additionally, given the relationship between emotion regulation and HRV (Mather & Thayer, 2018), it would be worthwhile for future esports interventions to implement techniques centred on improving emotion regulation to reduce physiological stress and improve gamer performance, as lower HRV is linked to better cognitive performance (Forte et al., 2019).

This study advances our knowledge of the physiological impact of gaming, highlighting potential differences in game genres in their impact on physiological responses. To conclude, this study highlights the need for focus to be attributed to designing interventions centred upon helping gamers cope effectively, with particular attention attributed to competitive games, to improve gamers experience and overall performance.

CRediT authorship contribution statement

Sarah C. Cregan: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Adam J. Toth:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Methodology, Investigation, Formal analysis. **Mark J. Campbell:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.chbr.2024.100567>.

Data availability

Data will be made available on request.

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