DISSERTATION

AN EXPLORATION OF VARYING ATTENTIONAL FOCUS STRATEGIES ON THE EXERCISE EXPERIENCE

Submitted by

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ABSTRACT

AN EXPLORATION OF VARYING ATTENTIONAL FOCUS STRATEGIES ON THE EXERCISE EXPERIENCE

Background: Research indicates attentional focus (AF) has a significant impact on the overall exercise experience, however, little is known regarding *how* AF manipulations via the use of distracting technology exerts a beneficial influence on the exercise experience. Additionally, the effect of varying AF strategies on the exercise experience may vary based on individual characteristics and/or familiarity with the exercise task. *Purpose:* The goal of Study 1 was to determine if distinct exerciser profiles could be created from a sample of group fitness participants. The goal of Study 2 was to determine if AF mediates the relationship between immersive virtual reality (VR) technology and ratings of perceived exertion (RPE)/enjoyment during an exercise session. *Methods:* In Study 1, a sample of group fitness participants (n=31) completed one traditional cycling class in which only audio cues were presented (AUD) and one video-enhanced immersive cycling class (IMM) in which a combination of music and video images was presented. After each cycling session, participants complete a brief survey that asked them to rate their perceived exertion, AF, and enjoyment of the exercise sessions. In Study 2, additional study volunteers (n=84) were randomly assigned to complete either an audio-only cycling class or an immersive VR-enhanced cycling class in which a combination of music and video images was presented. After cessation of the exercise session, participants completed a brief survey regarding their experiences in which they reported their recalled, in-task AF, RPE, and level of exercise enjoyment. *Results:* Study 1 leveraged Latent profile analysis (LPA) which indicated three, distinct classes could be drawn from the sample of 31 group fitness participants. These classes were classified as Low Heart Rate (HR) Dissociator, High HR Dissociator, and Associator. Results of Study 2 indicated AF did not act as a mediator relating immersive technology with RPE and exercise enjoyment (n=84). Additionally in Study 2, experimental condition did not have a significant influence on AF, RPE, or enjoyment directly, however, post-hoc, exploratory analyses revealed that average heart rate and time spent working in a moderate to vigorous heart rate zone (i.e., time spent at 70% or greater of age calculated heart rate maximum) were significantly greater in the immersive video enhanced condition than the audio only. *Conclusions:* Study 1 expands on the extant literature by elucidating the different attentional focus techniques used by different groups of exercisers and the varying response patterns of these sub-groups on commonly assessed exercise experience variables. Study 1 demonstrates the need for a deeper exploration of how individual characteristics differentially impact the exercise experience and how emerging analytical techniques can be employed to create more targeted interventions. Study 2 suggests that although AF was not a mediator relating immersive technology to RPE and exercise enjoyment, this technology does seem to exert a beneficial influence on the exercise experience as evidenced by the increased work rate found in this study. The results of Study 2 suggest future research should seek to identify other causal mechanisms that explain how immersive technology exerts its beneficial influence on the exercise experience.

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Since being introduced by Morgan and Pollock (1977) the role of attentional focus (AF) during exercise has continued to gain prominence within the literature. Today numerous conceptualizations, measurement techniques, and theoretical underpinnings exist all attempting to capture the dynamic and complex role of AF during physical activity (PA; Alvarez-Alvarado et al., 2019; Brick, et al., 2014; Ekkekakis, 2009; Hutchinson & Tenenbaum, 2007; Jones & Ekkekakis, 2019; Lind et al., 2011; Salmon et al., 2010). One such area of inquiry has sought to determine how different types of exercisers use and benefit from varying AF strategies.

Attentional Focus

Many studies support the use of AF manipulations to alter the experience of exercise (Bird et al., 2019, 2021; Bourke et al., 2021; Chow & Etnier, 2017; Ekkekakis, 2013; Gillman & Bryan, 2020; Glen et al., 2017; Gottschall & Hastings, 2017; Hutchinson et al., 2015, 2017; Hutchinson & Karageorghis, 2013; Jones et al., 2014; Jones & Ekkekakis, 2019; Limmeroth et al., 2022; Lind et al., 2011; Lohse & Sherwood, 2011; Mouatt et al., 2020; Neumann & Heng, 2011; Neumann & Piercy, 2013; Pottratz et al., 2021; Salmon et al., 2010; Schücker et al., 2014; Slater & Sanchez-Vives, 2016; Terry et al., 2012). Although many definitions of AF exist, the dichotomous association/dissociation conceptualization has been used for decades in the literature. Based on this model, attention can be either associative (focused on internal bodily sensations) or dissociative (focused on external, distracting stimuli; Tammen, 1996). While others have claimed this definition is too simplistic to capture the multiplex nature of attention during PA (Stevinson & Biddle, 1998; Wininger & Gieske, 2010), research indicates when tested with other dimensions (e.g., internal vs external) only the binary association/dissociation (A/D) has been found to have predictive utility (Stanley et al., 2007).

A primary application of the A/D construct has been to alter AF to make the exercise experience more enjoyable. Research consistently demonstrates people will continue to engage in activities they find enjoyable; therefore, by making PA more pleasurable it is possible exercise adoption and adherence rates will increase (Ekkekakis et al., 2008; Rhodes & Kates, 2015; Stevens et al., 2020). In a recent study by Oselinsky et al. (Manuscript Under Review), researchers attempted to manipulate attentional focus using an immersive VR simulation. In this study, 31 participants were instructed to take one traditional, audio-only cycling class and one video-enhanced, immersive virtual reality (VR) cycling class. Although AF was not significantly different between conditions, attention was more dissociative in the VR condition than in the traditional audio-only. Additionally, RPE was significantly lower, and enjoyment was significantly higher in the VR condition. Crucially, actual exertion, as indicated by the percentage of time spent in 70% or greater of one's maximum heart rate zone, did not differ significantly between conditions. This led the authors to conclude the use of the VR simulation resulted in participants enjoying the class more and feeling like they were not working as hard while still exercising at an intensity sufficient to produce desirable health benefits (Oselinsky et al., Manuscript Under Review). Several additional studies suggest dissociative AF might be a mechanism through which awareness of uncomfortable bodily sensations is suppressed and feelings of positive affect are enhanced (Baños et al., 2016; Bourke et al., 2021; Brick, et al., 2014; Cheval et al., 2020; Emad et al., 2017).

Although inducing a dissociative focus of attention seems to result in greater feelings of positively-valanced affect this effect is likely not universal. While beneficial for some, one's level of familiarity with the PA tasks seems to determine, in part, the efficacy of dissociative AF to create a more positive exercise experience. In their review, Lind et al. (2009) summarized the state of the AF literature concluding that generalizations cannot be made as both dissociative and associative strategies have been found to be beneficial depending on the exerciser's goals. The authors assert for those who are new to PA (i.e., untrained, or less-trained individuals), a dissociative AF is likely beneficial as it allows the exerciser to divert attention away from adverse physiological sensations (i.e., muscle burn, fatigue, difficulty breathing, etc.) therefore reducing perception of effort and fatigue. In this way, dissociative focus has been found to elicit positive affect and according to some, greater exercise adherence (Rhodes & Kates, 2015; Stevens et al., 2020). Conversely, associative AF has been shown to be beneficial for those who are familiar with the exercise task (i.e., well-trained individuals) as focusing on bodily sensations can result in optimal performance (Masters & Ogles, 1998; Morgan & Pollock, 1977). An abundance of literature supports the beneficial effect of associative AF for those familiar with the exercise task, especially athletes (Brewer & Buman, 2006; Neumann et al., 2022; Schücker et al., 2014; Stevinson & Biddle, 1998; Tammen, 1996, 1996; Whitehead et al., 2018).

Athletes

In their seminal paper which initiated the outpouring of interest in AF research within exercise psychology, Morgan and Pollock (1977) conducted interviews with elite marathon runners, regular marathon runners (as determined by finishing time; those categorized as elite completed the marathon in under 2.5 hours, those characterized as regular completed the race in 4-4.5 hours), and collegiate runners to determine what these groups thought about during a long-distance run. Contrary to their expectations that marathoners would dissociate to avoid the pain induced by running long distances, those in the elite group reported using associative AF strategies when completing long distance runs. This group reported focusing primarily on bodily input such as sensations from their calves and feet as well as their breathing. In order to monitor pace, rather than looking at a clock to track time, these athletes chose to pace themselves by "reading their bodies" (1977). This finding was surprising as previous work demonstrated other athletes typically employed a dissociative AF as a means by which to suppress painful physiological sensations leading to continued engagement with PA tasks (Watson, 1973). The authors believed the elite marathon runners interviewed for this study might have been a unique subset of the running population as indicated by their superior marathon finishing times, and this difference in expertise could have accounted for the unique AF strategy employed. Although this study of runners was the first to identify the use of associative AF strategies in endurance sport, since their publication several other studies have confirmed these results with other groups of athletes (Brewer & Buman, 2006; Neumann et al., 2022; Schücker et al., 2013; Silva & Appelbaum, 1989).

Twenty years after the results of Morgan and Pollock (1977) stunned the exercise psychology world, Masters and Ogles (1998) reviewed the substantial body of work on AF strategies completed during the preceding two decades. Supporting the results of Morgan and Pollock (1977), the authors concluded that, in general, association leads to better performance whereas dissociation can inhibit performance; association tends to be the preferred cognitive strategy employed during competitions and dissociation is preferred during training; and dissociation does not lead to increased rates of injury (Masters & Ogles, 1998). Although numerous studies support the use of dissociative AF for untrained or less-trained exercisers and association for athletes (Brick, et al., 2014; Denis et al., 2022; Lind et al., 2009; Longman et al., 2014; Neumann & Heng, 2011; Olson et al., 2018), less work has focused on identifying the optimal AF strategy for regular or well-trained exercisers.

Well-trained Exercisers

Well-trained recreational exercisers, arguably the most important subset of exercisers to help researchers best understand the mechanisms supporting long-term adherence to PA, have received limited attention in the extant literature. Experienced or well-trained exercisers are those who routinely engage in PA unrelated to athletic competitions (Reifsteck, 2013). As individuals become accustomed to the uncomfortable physiological sensations that occur as a result of PA, it is theorized they learn to observe these sensations in an unemotional way (Brewer & Buman, 2006; Leventhal & Everhart, 1979). This ability to separate pain and emotion is thought to develop over time and contribute to exercise adherence (Brewer & Buman, 2006). As well-trained exercises are neither novice (i.e., less-trained individuals) nor elite and might have varying emotional responses to the pain induced by exercise, it is possible the AF strategies employed by these exercisers might differ from those of the aforementioned groups.

To determine the impact of AF strategies on enjoyment, mood, and perceived exertion, Jones et al. (2021) randomly assigned 21 male recreational joggers to use either associative then dissociative AF or vice versa during separate, moderate-intensity exercise bouts. A secondary goal of this study was to determine how AF impacts performance measured via jogging speed. The authors hypothesized joggers would experience greater enjoyment, desirable changes in mood, and fewer distressing thoughts when dissociating. Additionally, they hypothesized RPE would be lower in the dissociative condition but time to complete the 1.5-mile run would be longer than when using an associative strategy. These hypotheses were partially supported. A time x condition interaction was found such that using the dissociative strategy first resulted in greater mood benefits (as indicated by decreased tension, depression, and confusion) than when the associative strategy was used first. No differences in RPE or time required to complete the 1.5-mile run were found between groups indicating that at moderate intensities attentional focus does not seem to impact performance for well-trained, experienced exercisers. From an applied perspective the authors recommend for both well-trained and less-trained exercisers seeking to maximize the psychological benefits of PA, a dissociative AF strategy should be used as it prevents both groups of exercises from monitoring adverse physiological sensation and reduces feelings of discomfort that arise as a result of moderate-to-vigorous PA (Jones et al., 2021). While reducing discomfort during exercise might be a goal for less-trained exercisers, this may not be a ubiquitous goal for well-trained exercisers and the AF strategy employed during exercise might vary depending on the exerciser's motivation.

In their study, Jones et al. (2017) examined two psychological characteristics which they asserted might predict people's responses to an exercise class; preferred attentional style and contextual motivation. The authors suggest attention and motivation might be "intimately tied" in that stimuli with motivational significance (i.e., those which fulfill a particular need) will receive preferential attention. When applied to PA, participants were hypothesized to be either Associators or Dissociators. Associators are intrinsically motivated to engage in PA as they derive pleasure or enjoyment from the act of moving their body. Dissociators are influenced by external rewards such as achieving a desirable body shape. Accordingly, the authors hypothesized those with a preference for association (i.e., Associators) would experience more positive outcomes from an exercise class than those who prefer dissociation (i.e., Dissociators) as the exercise class is more likely to directly fulfill the needs of Associators. Data were collected from 417 female participants. All participants were instructed to complete one moderate-to-vigorous intensity aerobic exercise class. Data were collected prior to and after completion of the class. The authors' hypothesis that Associators would experience more-positive psychological and behavioral outcomes was supported as Associators exhibited significantly more positive affective, cognitive, and behavioral outcomes and reported an increased likelihood of engaging in exercise in the future. The authors suggest that for those who are externally motivated (Dissociators), distracting stimuli might enable increased tolerance of the exercise class resulting in continued participation. Finally, the authors concluded that their study provides support for the attention-motivation relationship (Jones et al., 2017).

In their studies, Jones et al. (2017) and Jones et al. (2021) only examined participants of the same gender (females and males respectively). While each study advanced the literature on AF in well-trained exercisers, Emad et al. (2017) assert gender could be an important determinate of AF as based on their motivation for exercise, male and female regular exercisers might opt to employ different AF strategies. Utilizing a more complex conceptualization of AF proposed by Wininger and Gieske (2010), the authors broke AF down based on task relevance (association/dissociation) and direction (internal/external). According to this model, attention can be categorized as one of four types: 1) task-relevant internal which is comprised of focusing on internal bodily sensations such as breathing or heart rate. This category can be further broken down into a focus on strategy/goal setting (task-relevant thoughts) or internal dialogue such as encouragement or telling oneself to relax (self-talk); 2) task-relevant external which focuses on performance cues such as pace or, in the context of running, distance run; 3) task-irrelevant internal which consists of using a mental distraction such daydreaming or rumination; 4) task-irrelevant external which involves focusing on external stimuli such as the scenery or music/video (Emad et al., 2017; Wininger & Gieske, 2010). The authors postulate that in general, females might be driven to exercise for aesthetic purposes (i.e., to achieve a desirable body shape) and/or to maintain social acceptance whereas males might be motivated to exercise for competitive purposes or due to other external demands such as keeping up with friends. Based on these motivations the authors hypothesized females would adopt a task-relevant internal focus more frequently than males but adopting this focus would result in greater perceived exertion and decreased satisfaction and enjoyment. Males were hypothesized to primarily utilize a task-relevant external focus which would be associated with decreased perceptions of exertion and increased satisfaction and enjoyment. Accordingly, this study had two aims, 1) describe the frequency with which well-trained exercisers employed different AF strategies, and 2) test the relationship between AF strategies and perceived exertion, satisfaction, and enjoyment. Three hundred twenty participants (176 female, 144 male) completed this study. Participants reported their AF, RPE, enjoyment, and satisfaction during an exercise session. All exercisers demonstrated attentional flexibility employing multiple types of AF strategies throughout the exercise session. On average, males spent more time attending to task-relevant thoughts than females and attended to external cues more frequently. Females spent more time focusing on task-irrelevant thoughts and external distractions. For both genders, a higher proportion of task-irrelevant thoughts was inversely correlated with perceived exertion and satisfaction. For females, time focusing on external distractions was negatively correlated with satisfaction but positively correlated with enjoyment. Time focusing on task-relevant external cues was positively correlated with RPE and enjoyment for males only. This study therefore suggests male and female well-trained exercisers adopt different AF strategies and these strategies differentially impact the psychological outcomes of an exercise session (Emad et al., 2017).

Based on the extant literature, it is likely exercisers employ different AF strategies depending on familiarity/experience with the exercise task (i.e., well-trained vs less-trained) and individual characteristics such as gender or motivation. Given the possible variability in AF strategies employed during an exercise session and the impact the choice of strategy may have on the overall exercise experience (and therefore on future exercise participation), it is essential researchers strive to understand for whom different intervention elements will have a beneficial effect. To that end, the goal of the present study is to determine if distinct exerciser profiles can be created from a sample of group fitness participants.

STUDY 1 METHOD

This study consists of a post hoc, exploratory analysis of the data from Oselinsky et al. (Manuscript Under Review). The methods are, therefore, identical. For a full description of the methodology, please see Oselinsky et al. (Manuscript Under Review). A brief overview of the methods will be described here.

Participants

Thirty-one participants were recruited via convenience sampling from a group fitness studio located in the Eastern United States. All participants were members of the gym and agreed to complete two cycling classes within a two-week period. One cycling class was a traditional, audio-only class (AUD) and the other was a virtual reality, video-enhanced cycling class (VR). Participants' average age was 43.0 years (SD=14.9), and the sample was predominately female (77%). The average BMI of the sample was 24.2 (SD=2.7; Range=18.3-29.3).

Measures

Heart Rate

Heart rate (HR) data was collected using short-range radio telemetry and was broken down into zones calculated by subtracting the participant's age from 220. Zones were 70-79% of one's maximum HR, 80-89%, or 90-100% (Polar Electro Inc, Bethpage, NY).

Survey

Rating of Perceived Exertion: Participants were asked to rate their recalled level of exertion using a modified version of Borg's Ratings of Perceived Exertion (RPE) scale. This scale was altered by asking participants to report their *recalled* exertion rather than reporting real-time perceived exertion (Borg, 1982; Graupensperger et al., 2019). This single item measure asked participants to “Rate how hard you had to exert yourself during the class you just completed. Focus on your total feeling of exertion. Do not focus on just one factor (i.e., shortness of breath or leg pain). Circle the number that best describes your exertion”. Responses ranged from 6 (no exertion) to 20 (maximal exertion).

Day/Time: Participants were asked to report the time of day the exercise session took place as well as the day of the week.

Affective Responses/Enjoyment: Participants were asked a series of questions regarding their affective experiences and enjoyment of the exercise session. Questions such as “I like the amount of physical activity I got from this class” and “Rate your enjoyment with this class” were included. Responses were scored on a 7-point Likert scale ranging from 1-not at all to 7-extreme. Participants were also asked to rate how they felt during the exercise session using the 11-point Feeling Scale, a valid and reliable assessment of affective valance, with responses ranging from -5 (Very Bad) to +5 (Very Good) (Gillman & Bryan, 2020; Hardy & Rejeski, 1989; Karageorghis & Jones, 2014; Maher et al., 2015).

Association/Dissociation: Using the single-item measure by Tammen (1996), participants were asked to self-report their AF during the exercise session on an 11-point Likert rating scale. Responses ranged from 0=dissociative to 10=associative. This measure has been found to be an efficient and valid way to assess recalled in-task AF immediately following the cessation of exercise (Alvarez-Alvarado et al., 2019; Masters & Ogles, 1998; Tammen, 1996).

Procedure

Participants were recruited via emailed announcements at the gym where data collection took place. Eligibility criteria stated participants must be members of the gym, healthy, and free of conditions that would prevent them from engaging in two 40-minute cycling sessions. Lastly participants must have been able to complete the two classes on different days, within a two-week period. After obtaining informed consent, heart rate monitors were distributed and worn for the duration of the cycling classes. After each class session, participants completed an experience survey assessing RPE, affect/enjoyment, and AF.

STUDY 1 ANALYSES

Latent profile analysis (LPA) was utilized to determine if distinct profiles existed within the data. Specifically, the goal of this analysis was to determine if profiles are apparent for exercisers who could be considered "less-trained" or "novice" versus those who could be considered "experienced" or "well-trained" or if distinct profiles are constructed based on gender or a combination of these and/or other factors. Profiles were created using participants' self-reported RPEs, AF, enjoyment, time spent at 70% or greater of a participant's maximum heart rate, self-reported gender, age, and body mass index (BMI).

One through 4-class models were estimated using Mplus version 8.8 (Muthén & Muthén, 2107). There were no missing data however, this study utilized the maximum likelihood estimation method which is the recommended strategy for managing missing data (Schafer & Graham, 2002). Model fit indices were determined in accordance with the recommendations of Nylund et al. (2007).

To determine model fit, Nylund et al. (2007) recommend evaluating four model fit criteria; the Lo-Mendell-Rubin likelihood ratio test of model fit (LMR; Lo et al., 2001), the Bayesian Information Criterion (BIC; Schwarz, 1978), entropy (Celeux & Soromenho, 1996), and average latent class probabilities. Two additional model fit criteria were also evaluated: probabilistic class size and substantive interpretation.

The first criterion used to assess model fit was the LMR test. The LMR is used to test if a model with k profiles fits significantly better than model with k-1 profiles. If the test result was statistically significant as determined by a p-value<0.05 for this study, this indicated that a model with *k* profiles fit significantly better than a model with *k*-1 profiles. The next criterion used to assess model fit was BIC. Values closer to zero indicate better model fit. The third criterion that was evaluated was entropy which is considered an index of model classification quality. Entropy values range from 0-1 with values closer to one indicating better classification quality. Average latent class probabilities were used to determine how distinct the profiles are from one another using a matrix table. Values of one along the primary diagonal indicate perfectly distinct profiles. Classes were considered acceptably large if the smallest class represents at least 5% of the cases. Final model selection was based on the model fit indices, parsimony, and substantive interpretability of the model.

STUDY 1 RESULTS

Overall Model Fit

The 3-class solution provided the best overall model fit to the data (Table 1). Specifically, the 3-class model had the lowest BIC, the highest entropy value (excluding the 1-class model which will always have an entropy value of 1) and had the highest average latent class probabilities indicating the data was composed of three, distinct profiles. Examination of the LMR tests indicated the 3-class model was a significant improvement over the 2-class model and that the 4-class model was not a significant improvement over the 3-class model. The class breakdown in the 3-class model was reasonable with 74% of the sample belonging to the largest class, 23% to the mid-sized class and 3% belonging to the smallest class. While the smallest class is less than the stated acceptable class size of 5%, the authors opted to retain this class as closer examination of the data revealed a distinctly different response pattern than the other profiles.

Table 1 | Model Fit Indices calculated for 1-4 class models

Fit indices					
	1-class	2-class	3-class	4-class	* **Bold** indicates best
BIC	1552	1531	**1526**	1530	
Entropy	-	0.980	**0.987**	0.982	
ALCP	-	0.996-0.999	**0.996-1.00**	0.983-1.00	
LMR	-	0.220	**0.016**	0.620	
#/Class	31	7 (23%)	1 (3%)	7 (23%)	
		24 (77%)	7 (23%)	1 (3%)	
			23 (74%)	7 (23%)	
				16 (52%)	

Note. BIC= Bayesian Information Criterion; ALCP= average latent class probabilities; LMR= Lo-mendell-rubin likelihood ratio test.

Description of the Best Fitting Model

Table 2 presents the estimated means for each latent profile on each of the indicators included in deriving the profiles. The three classes in the best fitting model can be described as Low HR Dissociator, Associator, and High HR Dissociator. The Associator profile was associated with higher RPEs (i.e., participants with a high probability of belonging to this class worked hard and were aware of their effort), a predominately associative attentional focus, approximately equal enjoyment across both experimental conditions, and more time spent at 70% or greater of maximum HR in the AUD class than the IMM. The High HR Dissociator profile was associated with lower RPEs, a greater tendency to dissociate especially in the IMM class, greater enjoyment of the IMM class, and more time spent at 70% or greater of calculated maximum HR in the IMM class than the AUD. The average age of participants with a higher probabilistic membership in the Associator profile was ~10 years greater than those with a higher probabilistic membership in the High HR Dissociator profile and the average BMI was lower in the Associator profile compared to the High HR Dissociator profile. The last class, which the authors have categorized as Low HR Dissociator, represents a pattern similar to that of the High HR Dissociator class (Figure 1); however, time spent at 70% or greater of maximum HR was significantly lower than either of the aforementioned classes. This indicates the participant perceived they were working hard, near their maximum effort in the AUD class, but their HR indicates they spent ~40% of the time in both experimental conditions working at a light or lower intensity.

Table 2 | Average indicator response by class

Indicator	*Average indicator response*		
	Low HR Dissociator (n=1)	Associator (n=23)	High HR Dissociator (n=7)
RPE AUD[a]	18	17.57	15.58
RPE IMM	15	16.30	14.62
Attention AUD[b]	9	9.31	7.86
Attention IMM	8	8.91	6.32
Enjoyment AUD[c]	6	6.44	4.73
Enjoyment IMM	7	6.65	5.72
Time spent at 70%+ AUD[d]	**59.8**	93.53	92.64
Time spent at 70%+ IMM	**56**	90.90	95.14
Sex[e]	2	1.83	1.577
Age	60	44.42	36.03
BMI	18.24	23.97	25.54

Note. RPE= ratings of perceived exertion; AUD= audio only cycling condition; IMM= immersive, video enhanced cycling condition; Time spent 70+ = time spent at 70% or greater of one's age determined maximum heart rate; BMI= body mass index; HR= Heart rate.

[a]RPE (Rating of perceived exertion) was measured on a 15-point scale with anchors 6=no exertion and 20=maximal exertion.

[b]Attentional Focus was measured on an 11-point scale with anchors 0=dissociative and 10=associative.

[c]Enjoyment was assessed via a single-item measure that asked participants to rate their enjoyment of the exercise session. Item anchors were 1 (not at all) to 7 (extreme).

[d]Time spent at 70% or greater of maximum heart rate was created by calculating each participant's maximum heart rate as indicated via 220-age.

[e]Sex was dummy coded so 1=Male and 2=Female

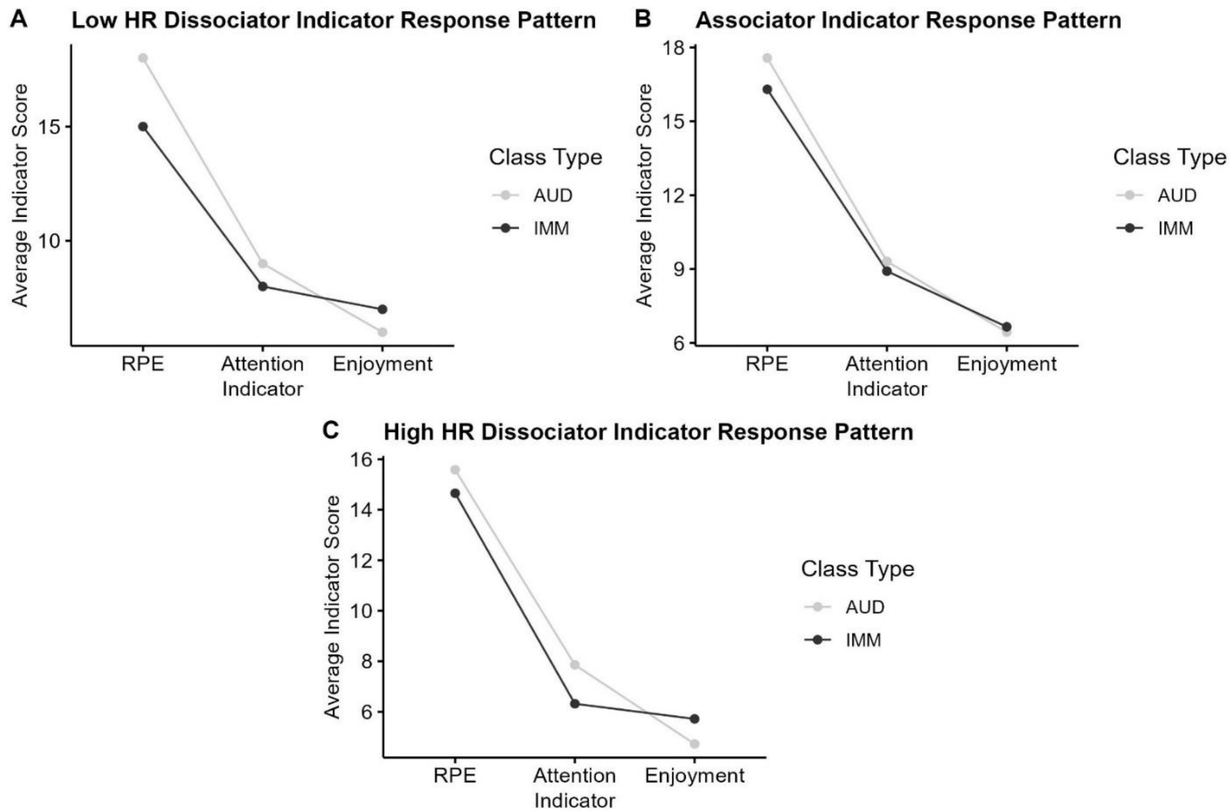

Figure 1 | Average indicator response pattern by class. HR= Heart rate; AUD= audio only cycling class; IMM= immersive, virtual reality enhanced cycling class; RPE= ratings of perceived exertion.

STUDY 1 DISCUSSION

This study sought to determine if distinct exerciser profiles could be created from previously collected exercise experience data. As this study was exploratory in nature, no a-priori hypotheses were formulated. The results of the study support the creation of multiple exerciser profiles from a sample of group fitness participants. The results indicate three distinct profiles can be created from the data; an Associator profile characterized by greater associative thinking in both experimental conditions, higher RPEs, equal levels of enjoyment across experimental conditions, and more time spent at 70% or greater of maximum HR in the AUD condition than the IMM. A second profile could be described as High HR Dissociators, as it was characterized by greater levels of dissociative AF, greater enjoyment in the IMM condition, lower RPEs in the IMM condition, more time spent at 70% of greater of maximum HR compared to the other dissociative profile, and more time spent at 70% or greater of maximum HR in the IMM condition when compared to the AUD. The final profile can be classified as a Low HR Dissociator characterized by high RPEs in both conditions, highly associative AF with more dissociative focus during the IMM condition, greater enjoyment of the IMM class than the AUD, and the least amount of time spent exercising at 70% or greater of maximum HR compared to the other profiles. These profiles may be related to level of exercise experience as the Associator profile seems representative of the response pattern displayed by experienced or well-trained exercisers, the High HR Dissociator profile closely mimics the response pattern of novice or less-trained exercisers, and the Low HR Dissociator profile may be representative of a new exerciser or untrained exerciser as their RPEs do not closely align with their time spent working in a moderate to vigorous heart rate zone. This study also supports the utility of leveraging structural equation modeling techniques to enable a nuanced examination of differing exercise experiences based on indicator response patterns.

The indicator response patterns used to create the 3-class model proposed in this study aligns with the results of Gottschall and Hastings (2017). In their study, the authors sought to determine if the combination of music + digital images differentially impacted the exercise experience for well-trained (more than 10 hours of PA/week) versus less-trained (less than 2 hours of PA/week) individuals. Twelve participants (6 well-trained and 6 less-trained) completed 16 cycling classes, half of which included music + digital images the other half included only music, across 8 weeks. In line with the results of this study, those classified as well-trained (Associator in the present study) spent more time in their maximum HR zone (80-100% HR maximum) and had higher RPEs during the audio only class than when music was combined with digital images. Conversely, less-trained individuals had lower RPEs when music and digital images were presented while time spent in their maximum HR zone did not differ between conditions, diverging from the results of this profile analysis in which time spent at 70% or greater of maximum HR was greater during the IMM condition for the High HR Dissociator profile. Lastly, although Gottschall and Hastings (2017) observed high satisfaction ratings overall, the less-trained individuals rated the music + digital images condition more favorably, further corroborating the profile classification created in this study. Additional evidence supporting the proposed profile classification comes from Jones et al. (2021). In their study of experienced recreational/well-trained joggers, enjoyment of the exercise session was the same regardless of which attentional focus strategy was employed (associative vs dissociative) as was the case in this study for the Associator profile. Taken together, the results suggest well-trained exercisers do not rely on a specific AF strategy to increase PA enjoyment.

An unexpected finding in the study was the classification of one individual into a separate profile. Although this class had a response pattern similar to that of the High HR Dissociator exerciser profile, there appears to be a distinct difference between these classes in terms of time spent cycling at a moderate or greater intensity as indicated by the HR data. In the High HR Dissociator profile, individuals spent the majority of the exercise sessions working at 70% or greater of their age determined HR maximum (~90%). In comparison, the individual in the Low HR Dissociator exerciser profile spent substantially less time working at a moderate-to-vigorous intensity (~60%). The research team suspects this might be indicative of an untrained exerciser as research indicates there is a habituation period during which RPE does not strongly correlate with actual HR for those who are new to or unfamiliar with an exercise task. After this habituation period, ratings of exertion stabilized and strongly correlated with actual HR (Astorino et al., 2016; Fearnbach et al., 2020; Grange et al., 2004; Jabbour & Majed, 2018; Muyor, 2013). An additional distinction between the classes is their BMI classification. The Low HR Dissociator profile which exhibits a low BMI, can be classified as underweight, the Associator profile's BMI can be classified as normal weight, and the High HR Dissociator profile has a BMI that can be classified as overweight. These BMI classifications are in line with previous work which indicates those who are overweight rely more heavily on dissociative techniques during PA as the adverse physiological sensations that accompany exercise are more pronounced for these individuals (Baños et al., 2016; Deforche & De Bourdeaudhuij, 2015). Additional research indicates that being underweight can result in increased levels of fatigue which might explain the RPE/HR discrepancy observed in this study (Uzogara, 2016).

These results should be interpreted with caution however, as BMI is not always a valid indicator of weight or health status, and because the Low HR Dissociator profile is represented by only one participant.

Strengths

Although there exist numerous studies exploring the relationships between AF, RPE, and affect/enjoyment during exercise (Bird et al., 2019, 2021; Brick, et al., 2014; Chow & Etnier, 2017; Ekkekakis et al., 2008; Gillman & Bryan, 2016, 2020; Hutchinson et al., 2015), this is the first study of which the authors are aware that attempted to create unique exerciser profiles based on response patterns to commonly assessed variables. Identifying distinct profiles enables the subsequent creation of tailored PA interventions designed to elicit a favorable response from heterogenous sub-populations. These types of targeted interventions may have a higher likelihood of achieving lasting behavior change such as increased exercise adoption and adherence rates. Additionally, this study opens the door for exploration of other empirically supported interventions which have, at the population level, had little effect. By leveraging these analytical techniques, we can gain deeper insights into which intervention elements are beneficial for different groups of individuals, thus enhancing our understanding of intervention effectiveness.

This study was one of only a handful of studies conducted in an ecologically valid setting. Although an experimental laboratory setting allows for maximum research control, this study may more accurately reflect real world behavior as the data were collected from a for-profit fitness studio. These results may be more readily generalizable to the real world as the data are more likely to reflect the everyday actions of group fitness participants. Those who participated in this study were also diverse in terms of age and weight status (Age range: 20-64;

BMI Range: 18.24-29.27) further increasing the generalizability of the results. Finally, this study employed only measures that have been found to be both valid and reliable indicators of the constructs they intend to assess (Gillman & Bryan, 2020; Graupenspeger et al., 2019; Haddad et al., 2017; Hardy & Rejeski, 1989; Karageorghis & Jones, 2014; Maher et al., 2015; Masters & Ogles, 1998).

Limitations

Although this study supports the identification of three distinct exerciser profiles, these results should be interpreted with caution due to several limitations. First, as with any latent profile analysis, the interpretation and categorization of the classes based on the indicator response patterns is subjective. While supported by the literature, there is no way to definitively determine if the profile classifications proposed in this study are substantively correct or if these profiles exist in the real world. While a useful analytical tool, the results of any LPA are only analytical summaries and the findings should not be treated as though they are absolute or have a concrete reality (Bauer, 2022). Although viewed by some as a limitation, the non-definitive nature of latent profile classifications can also be viewed as a strength as these models acknowledge and account for unexplained variance. Unlike similar models such as cluster analysis which definitively assigns participants to specific sub-groups, accounting for this uncertainty increases the utility and generalizability of LPA models (Bauer, 2022).

Perhaps the most pronounced limiting factor of this study was the small sample size. With only 31 observations, the amount of data analyzed was substantially less than the minimally acceptable sample size suggested by Nylund et al. (2007). Although the general consensus in the literature is that more data is better, research suggests a minimum of 500 observations is necessary in order to confidently extract meaningful profiles (Nylund et al., 2007). With too little data, it is likely that the number of classes identified will represent bipolar (i.e., high and low) profiles with maximum between-group variability. What will be missed is more nuanced profiles that likely exist but may fail to be captured as there is insufficient data available to craft these more specific profiles. For example, this study produced an unexpected third profile comprised of only one individual who did not have a high probabilistic membership in either of the other two larger classes. Closer examination revealed that this profile is likely distinct from the Associator or High HR Dissociator classes due to a significantly different heart rate response pattern. Without additional data, the research team cannot confidently determine if this class represents an additional profile derived from a distinctly different response pattern, or if this profile is indicative of over-classification (Bauer, 2022; Nylund et al., 2007). This is a clear limitation of the small sample size used in this study as the research team cannot determine the implications of this profile (e.g., does this class represent a profile under-classification and suggest that while this study was successfully able to identify two classes, it failed to extract additional profiles comprised of individuals who do not neatly fall into one of the two larger classes or is this over-classification in which too many profiles were extracted from too little data?). While the sample size obtained in this study is less than what is traditionally recommended, a simulation study by Lubke and Neale (2006) found that when entropy values are close to one, a sample with as few as 25 observations can result in correct model specification, increasing confidence in the present study's findings.

This study also lacked the inclusion of auxiliary variables. Auxiliary variables can be included after the final model has been identified and provide additional insight into characteristics which predict profile membership and can serve as a means to validate the accuracy of the model. These variables can either be predictor variables which can be added to the final model to determine if theoretically relevant variables significantly predict class membership, or distal outcomes in which the utility of the profiles to predict relevant outcomes can be examined. Both techniques enable verification that the profile classifications are accurate creating a deeper understanding of who might belong to each profile and the impact class membership has on relevant outcomes. For example, this study would have benefitted from the inclusion of a predictor variable that assessed movement pleasure and a variable which directly assessed level of exercise experience. If level of experience is the true latent construct driving class membership in the present model, then a measure of exercise experience should significantly predict profile membership. It is also possible that the profiles have nothing to do with level of exercise experience but rather represent the theoretical construct of Associator vs Dissociator as proposed by Jones et al. (2017). Including a measure of movement pleasure (i.e., do you derive pleasure from moving your body) and adding this as a predictor to the model would help the research team determine if the underlying latent construct is actually exercise familiarity or something else such as AF preference. Additionally, including distal outcome variables would enable the verification of model accuracy and increase the model's applied utility by determining if the profile classifications can predict meaningful outcomes.

Future Directions

Future research should seek to confirm the accuracy of the model results by conducting an additional LPA with a larger, confirmatory sample. In doing so, profile accuracy can be verified and more classes may possibly be extracted. A confirmatory study would also enable future researchers to characterize the classes with more confidence. By including a larger sample size, the resulting classes will likely be significantly more specific, possibly revealing additional, distinct exerciser profiles. To increase the real-world applicability of the profiles, auxiliary variables should also be measured. The inclusion of predictor variables will increase confidence that their classification taxonomy is representative of the true underlying latent construct. From an applied perspective, the identification of significant predictor variables may enable easier profile assignment allowing for the correct intervention to be applied within specific sub-populations of interest. Including distal outcome variables will also increase the applied utility of this type of classification model as it will allow researchers to determine if profile assignment predicts meaningful outcomes such as long-term exercise adherence or increased exercise adoption.

Conclusions

This study identified three distinct exercises profiles classified as Associator, High HR Dissociator, and Low HR Dissociator within what was previously thought to be a homogenous sample of group fitness participants. This study both supports and expands on the current literature by highlighting the different attentional focus techniques used by different groups of exercisers and illuminates the varying response patterns of these sub-groups on commonly assessed exercise experience variables. Specifically, this research suggests that incorporating an AF manipulation into exercise settings may only result in a more positive exercise experience (as evidenced by lower RPEs and greater enjoyment) for some individuals, in this case those who had the highest probabilistic membership in the Dissociator profiles. Finally, this study demonstrates the need for deeper exploration of how individual characteristics differentially impact the exercise experience and how emerging analytical techniques can be employed to create more targeted interventions.

AN EXPLORATION OF VARYING ATTENTIONAL FOCUS STRATEGIES ON THE EXERCISE EXPERIENCE; STUDY 2

A substantial shift has occurred within the exercise psychology literature as researchers recognize the limited beneficial effects of physical activity (PA) interventions that rely on promoting the benefits of exercise to increase PA adoption and adherence (Conroy & Berry, 2017; Ekkekakis et al., 2013; Kwan & Bryan, 2010). Although increasing perceived benefits is a theoretically sound avenue through which behavioral modification is hypothesized to be successful, a fundamental flaw of interventions built around this avenue is the assumption of rationality. Interventions which highlight the beneficial effects of exercise for physical and mental health assume that people will engage in PA because the benefits of doing so are well understood. While this type of intervention can be successful for some, for the majority, these interventions have failed to result in sustained increases in PA (Bird et al., 2019; Bluemke et al., 2010; Brand & Ekkekakis, 2018; Ekkekakis, 2017; Schneider et al., 2023). An alternative approach gaining prominence in the literature is to focus instead on increasing positive affective experiences both during and following the cessation of exercise.

Physical Activity and Affect

According to hedonic theories of behavior, people will continue to engage in activities they find pleasurable (Rhodes & Kates, 2015). When applied to exercise research, several reviews support the utility of manipulating affective experiences of exercise to increase PA initiation and maintenance. The role of affect on exercise has been described by Ekkekakis et al. (2013, p.751) as one of the most "vibrant and prolific areas of research within exercise psychology." Indeed, a systematic review of 20 studies by Rhodes and Kates (2015) found affective judgments to be one of the strongest correlates of physical activity behavior. Additionally, this 2015 review concluded that positive changes in affect during moderate-intensity PA were consistently linked to future PA behavior with effect sizes ranging from small to large (Rhodes & Kates, 2015). Additional research supports the importance of affect demonstrating a strong relationship between positive affective experiences and continued PA engagement (Schneider, 2018; Stevens et al., 2020). While improving one's affective experience during exercise is seemingly a simple solution to increase rates of activity, affective experiences of exercise are closely tied to exercise intensity (Alvarez-Alvarado et al., 2019; Ekkekakis, 2009; Ekkekakis et al., 2008). At low intensities affect is generally positive. As intensity increases and approaches the ventilatory threshold (VT; the point at which breathing becomes difficult and speech is no longer possible; Thompson, 2017) there is a near universal shift in which affect becomes increasingly negative until exercise is either terminated or intensity decreases (Alvarez-Alvarado et al., 2019). As the most beneficial health effects of exercise are derived from working at moderate to vigorous intensities there is a clear need for tools or techniques enabling the maintenance of positively-valanced affect even as intensity approaches or exceeds the VT.

Attentional Focus

One approach thought to improve positive affective experiences of exercise, is to alter attentional focus (AF). While the literature lacks consensus regarding the terminology and measurement of attentional focus, in general evidence supports the use of distracting techniques to reduce feelings of exertion and to increase positive affect especially for those new to exercise (Mouatt et al., 2020; Stevinson & Biddle, 1998; Wininger & Gieske, 2010). In its most simplistic form, attentional focus is thought to be a dichotomous construct in which attention is either focused internally on bodily sensations (association) or externally via distraction (dissociation;

Masters & Ogles, 1998; Morgan & Pollock, 1977; Tammen, 1996). As with affect, attentional focus can be impacted by exercise intensity. At low intensities, attention is able to freely flip from associative to dissociative. As intensity increases it becomes harder to divert attention away from uncomfortable bodily sensations until the point (typically around the VT) at which one can no longer suppress their awareness of bodily sensations and attention is forced to remain associative (Alvarez-Alvarado et al., 2019). Research has sought to identify tools which prevent the attention shift from dissociative to associative AF when exercising at moderate to vigorous intensities. It is hypothesized if attention can remain dissociative even during strenuous PA, then affect can remain positive resulting in greater adherence to exercise performed at uncomfortable but health enhancing intensities.

Distracting Technology

The most commonly tested and consistently effective tool to elicit dissociative AF is music. Numerous studies confirm the utility of music to distract attention away from negative bodily sensations resulting in increased speed, power, duration, and intensity of PA (Ekkekakis et al., 2013; Hutchinson et al., 2015, 2017; Jones & Ekkekakis, 2019; Terry et al., 2012). Additionally, research indicates that music can have a significant and positive effect on hormonal and physiological responses to exercise as well. Studies suggest the distracting effects of music can mask the physiological and neuroendocrine responses to physical activity resulting in lower heart rate variability, decreased cortisol, ACTH, and epinephrine secretion, and reduced activation of the sympathetic nervous system; however, this effect may be dependent on the type of music presented and the exercise intensity (Bigliassi et al., 2015; Conrad et al., 2007; Szmedra & Bacharach, 1998; Yamashita et al., 2006). Although promising, the ability for music to shift attention externally is limited. As intensity approaches the VT, the beneficial effects of music are short-lived, lasting on average a few minutes before attention is forced inward (Hutchinson & Karageorghis, 2013; Karageorghis & Jones, 2014). One theory explaining why the beneficial effect of music cannot be sustained as intensity approaches or exceeds the VT is that it does not occupy enough cognitive load. Working memory has a finite capacity to process incoming information, therefore attentional resources are allocated to only the strongest stimuli (Brewer & Buman, 2006). Although music can be a strong stimulus at low to moderate intensities, as exercise intensity increases, physiological sensations begin to dominate conscious awareness. Accordingly, based on the theory of cognitive load, stronger external stimuli could result in a sustained dissociative AF even at intensities at or above the VT (Jones et al., 2014; Jones & Ekkekakis, 2019).

Immersive Technology

As technology has become more sophisticated and accessible, the use of immersive technologies within the exercise domain is becoming increasingly common. Virtual reality (VR) is an immersive technology that attempts to create a sense of presence within a fictional world (Slater & Sanchez-Vives, 2016). Several studies have tested the impact of exercising while viewing virtual environments on participants' experiences of exercise. Bird et al. (2021) found that exercising in VR and VR + music resulted in greater enjoyment and more positively valanced affect than exercising with music alone. Similarly, Martin-Niedecken et al. (2020) and Bird et al. (2019) found evidence that even during high-intensity exercise, VR technology improved enjoyment and positive affect. Chow and Etiner (2017) were also able to elicit higher levels of enjoyment among healthy men exercising at high intensities and concluded VR reduced RPE. Hutchinson and Karageorghis (2015) determined there was a similar beneficial effect of music + video on participants' RPE, affect, and motivation. Oselinsky et al. (Manuscript Under

Review) concluded the use of immersive technology can increase feelings of enjoyment while decreasing RPE without impacting actual exertion.

Although these studies concluded immersive technology can be beneficial when used during PA, none sought to determine *how* these simulations have a positive impact on the exercise experience. In an attempt to clearly distinguish the underlying mechanisms that produce the observed beneficial effects, Bareto-Silva et al. (2018) utilized virtual reality technology to elucidate the impact of audiovisual stimuli on the psychological and neuroendocrine responses to exercise. The authors assert that the human brain is constantly recreating the external environment based on the processing of external sensory signals, interoceptive sensory information, and previous experience. When presented with audiovisual stimuli, the authors posit, humans have the tendency to imagine themselves within the story depicted by the external stimulus. In this way, Bareto-Silva et al. (2018) believe distracting audiovisual stimuli might be able to modulate psychophysiological responses to exercise as the person will imagine they are in the world created by the external stimulus, suppressing their awareness of what is going on in the real world. The researchers hypothesized that a) immersive environments would force people to picture themselves in the world depicted via the external stimuli, b) pleasant audiovisual stimuli would reduce autonomic nervous system activation, increase parasympathetic activity, and lower perceived exertion when compared with an unpleasant stimulus or neutral stimulus, and c) unpleasant audiovisual stimuli would have the inverse effect, heightening fatigue-related sensations, and down-regulating the activity of the parasympathetic nervous system. The authors recruited 20 individuals who participated in three experimental conditions in a randomized and counterbalanced order, each of which involved cycling for 10 minutes while different audiovisual stimuli were presented. In the first of three conditions, participants cycled while an unpleasant audiovisual stimulus was presented. In condition two participants cycled while being exposed to a pleasant audiovisual stimulus, and in condition three they cycled in the presence of a neutral stimulus. The authors found that pleasant audiovisual stimuli reduced both the perception of fatigue and the physiological stress imposed by the exercise session (as indicated via decreased heart rate variability). The unpleasant audiovisual stimuli increased the activity of the autonomic nervous system and increased perceptions of exertion to a greater degree than the pleasant stimulus. The authors concluded that audiovisual stimuli have the potential to up/down-regulate psychophysiological responses to exercise resulting in an additive physiological impact or suppression of the physiological response to PA. Additional work by Roth et al., (1990), Taelman et al. (2011), Thompson et al. (2020), Harte and Eifert (1995), and Webb et al. (2008, 2011) support the additive effects of focusing one's attention on a mentally stressful external stimulus or the masking effect of focusing one's attention on a neutral or positive external stimulus on the physiological and hormonal responses to exercise.

Research by Mouatt et al. (2020) sought to further clarify "the current state and nature of the literature investigating the use of VR in healthy and clinical populations to alter motivation, affect, enjoyment, and/or engagement during exercise" (Mouatt et al., 2020, p. 2). Their search identified 25 studies which were included in the review. Out of the 25 studies, nine included no theoretical justification for how immersive technologies alter perceptions of exercise. Of the remaining 16, half incorporated theories of attentional focus, seven of which specifically focused on the use of association/dissociation (A/D) to explain the observed effects.

Dating back to 1997, the oldest study in the review to include an explicit reference to A/D explored the impact of virtual reality-enhanced exercise equipment on PA attendance and adherence (Annesi & Mazas, 1997). The authors tested three different exercise bikes: a traditional upright exercise bike, a recumbent bike, and a virtual-reality enhanced exercise bike. Participants were assigned to one of the three exercise bike conditions and were instructed to record their attendance for 14 weeks as well as complete several surveys measuring individual characteristics and experiential variables. Those in the VR bike group attended significantly more sessions than the upright or recumbent groups (83.33%, 57.14%, and 61.54% respectively), however, post-exercise feelings of positive engagement, revitalization, tranquility, and physical exhaustion did not differ between the groups. Additionally, self-motivation scores were not associated with attendance or adherence. The authors believe the lack of differences between the groups is likely because the VR bike altered in-task experiences (which were not measured) by promoting greater dissociation, enjoyment, and variety but did not affect post-task experiences and the effects mediating the higher VR attendance were therefore not captured by the measures used in this study (Annesi & Mazas, 1997).

Two studies by Mester et al. (2011a; 2011b) were included in the review. In the first study, the authors used immersive video to test the impact of sensory input on performance, enjoyment, and attentional focus via a mixed-design cycling task. The authors used a 2x3x4 design with two types of feedback (video, video + music), three course phases (flat, uphill, downhill) and four sessions (task repetition). Overall, results indicated sensory stimulation did result in participants being distracted from the exercise intensity leading the authors to hypothesize VR evokes a dissociative attentional focus during exercise (Mestre, et al., 2011b).

The second study evaluated the impact of virtual feedback on RPE and enjoyment. The authors tested three VR conditions: cycling in VR with no feedback, cycling in VR while receiving real time feedback, and cycling in VR while receiving real time feedback with the presence of a virtual coach (Mestre et al., 2011a). The authors hypothesized the VR feedback and the VR feedback + coach would act as a distraction from negative affect therefore increasing enjoyment, and reducing RPE, boredom, and fatigue. VR feedback was found to be an effective distractor and the virtual coach further enhanced enjoyment by providing pacing and intensity cues enabling the participants to regulate their performance more effectively. Although their study produced informative results, the authors point out no causal chains were tested and that future research should seek to identify how VR, attentional focus, RPE, and enjoyment are causally related (Mestre et al., 2011a).

Similarly, Murray et al. (2016) evaluated how the presence of others while exercising in VR impacted performance and enjoyment. In their study, 60 participants were assigned to one of three rowing conditions; traditional rowing without VR, individual VR, or companion VR in which an avatar was present. Both VR groups performed better (i.e., rowed further and had a higher power output), did not perceive they were working harder, and had higher levels of enjoyment than the traditional group. Those who rowed in VR with a companion avatar rowed the furthest and had the highest heart rates indicating the presence of an avatar was beneficial for performance, supporting the results of Mester et al. (2011a). Although not directly tested, the authors speculate both VR conditions distracted attention away from adverse physiological sensations resulting in increased performance and enjoyment while RPE remained similar in all conditions (Murray et al., 2016).

Both Baños et al. (2016) and Jones and Ekkekakis (2019) expanded on the current work by testing immersive technologies with diverse populations. Baños et al. (2016) evaluated the use of VR in overweight children. They hypothesized VR would act as a distractor resulting in decreased perceptions of bodily sensations and this effect would be more pronounced for overweight compared to normal-weight children. They also anticipated differences in affect, perceived exertion, and enjoyment as the VR-enhanced condition was expected to create a greater sense of distraction than the non-VR, traditional walking condition. Here, they also thought the differences would be greater for overweight children as adverse physiological cues are more pronounced for this group and when present, distractions seem to be more effective. The authors concluded that their hypotheses were partially supported; VR did distract attention away from bodily sensations and this effect was greater for overweight children; however, no differences in affect or perceived exertion were found. The authors assert that the exercise intensity was not high enough to warrant the use of distraction as a technique to increase feelings of positive affect and lower ratings of perceived exertion. Finally, the VR condition did produce greater enjoyment than the traditional walking condition for both groups of children (Baños et al., 2016).

Jones and Ekkekakis (2019) tested two types of immersive technology to determine if one was superior to the other at evoking greater dissociative attentional focus. Twenty-one low active, overweight participants completed 15-minute cycling sessions at the VT in low immersion (audio + video), high immersion (VR head mounted display + audio), and no immersion/control conditions. The results indicated that high immersion resulted in greater dissociative attentional focus, increased pleasure from pre to post intervention, and demonstrated the highest levels of postexercise enjoyment compared to both the low immersion and control conditions. The authors theorized that the VR head-mounted display was more effective than the other experimental conditions as it required the use of more cognitive resources and therefore left little room for uncomfortable bodily sensations to occupy conscious awareness. Jones and Ekkekakis (2019) concluded VR head-mounted displays could be a useful tool to increase exercise adoption and adherence in overweight, low-active adults.

The most recent study included in Mouatt et al's. (2020) review attempted to correct what the authors assert could be a methodologic concern of previous studies. In their paper, Neumann and Moffitt (2018) argued using a blank environment in which no visual stimulus is presented as the comparator condition in experimental studies could make it difficult to determine how VR is impacting the exercise experience. The authors specifically sought to identify the role of presence when exercising using VR. Forty participants completed a treadmill running task in which they ran for 21-minutes at 70% of their VO2 max. One group ran while viewing a computer-generated VR environment and the other ran while viewing neutral images. In the VR condition, participants viewed themselves as a computer-generated avatar running through an outdoor, park-like environment. In the neutral images condition, participants were presented with images that were rated as low in arousal and neutral in valence (e.g., images of a clock, a basket, a whistle, buttons, etc.). Surprisingly, the neutral images condition produced greater levels of positive affect and lower levels of negative affect than the VR environment. One possible explanation for this could be because the VR condition elicited a greater focus on bodily sensations resulting in more negative affect. Alternatively, the authors suggest the VR environment failed to efficiently capture the participant's attention which might explain why affect was less positive in this condition compared to the neutral images condition. The authors conclude by warning against the use of *any* VR environment as their study suggests the utility of VR to positively impact the exercise experience may rely on the simulation's ability to capture a participant's attention (Neumann & Moffitt, 2018).

A commonality among these studies which is highlighted by Mouatt et al. (2020), is that while the authors of these studies discussed a theorized relationship among immersive technologies, attentional focus, and enjoyment, none explicitly investigated how the variables are causally related. In fact, the authors are unaware of any study which examines the causal chain relating these variables. Therefore, the goal of the present study is to evaluate if AF mediates the relationship between immersive technologies and RPE/enjoyment. We hypothesize that…

1. Attentional focus will mediate the relationship between immersive technology and RPE
2. Attentional focus will mediate the relationship between immersive technology and enjoyment
3. RPE and enjoyment will be inversely correlated

STUDY 2 METHOD

This study received approval from the authors' institutional review board and all participants provided written informed consent.

Participants

Participants (n = 85) were recruited in 2023 through convenience sampling from a large university in the Western U.S. In order to enroll in the study, participants had to self-report that they were willing and able to engage in a single, 20-minute session of self-paced exercise. Study volunteers could not be prone to motion sickness, must have been comfortable wearing a heart rate monitor while exercising, and must have been between the ages of 18-65. Finally, as the effect of immersive technologies seems to be most pronounced for low-active individuals, study volunteers were screened to confirm that they currently (i.e., over the past month) engage in less than 150-minutes of moderate-to- vigorous activity per week (MVPA). The cut-point of less than 150-minutes of MVPA per week was selected as this is the cut-point used by the Centers for Disease Control and Prevention to categorize individuals as insufficiently active (Centers for Disease Control and Prevention [CDC], 2016). One participant's data was removed from all analyses due to motion sickness. Participants were predominantly female (64%), and non-Hispanic White (81%). The average age of the participants was 28.7 years (*SD*=10.16) and the average BMI was 24.04 (*SD*=5.17).

Power Analysis

An a-priori power analysis was conducted using a Monte Carlo simulation via Mplus (Emery & Simons, 2020; Muthén & Muthén, 2107; Zhang, 2014). The effect of interest was the indirect effect which is the product of the a-path and b-path coefficients specified via a mediation model (Figure 2). Previous research has varied significantly in the estimation of effect sizes for the paths relating immersive technology, AF, and RPE/enjoyment with estimates for each path ranging from small to large depending on the study's methodology and type of immersive technology (Mouatt et al., 2020; Slater & Sanchez-Vives, 2016). In general, the literature supports at least a moderate effect of immersive technology on AF and a moderate effect of AF on RPE/enjoyment respectively (f=0.39, d=0.5; Mouatt et al., 2020). Results of the power analysis using 1000 bias-corrected bootstrap replications indicated a sample of at least 75 participants were necessary to detect a mediating effect of AF on the relationship between immersive technology and RPE/enjoyment with a power estimate of 0.84.

Apparatus/Measures

Apparatus

All exercise sessions took place indoors in a temperature-controlled environment using the Sunny Health & Fitness SF-B1002 indoor cycling exercise bike. This exercise bike has four adjustable parts: adjustable seat height, seat distance from handlebars, height of handlebars, and foot-strap tightness. Proper alignment recommendations were provided to participants at the start of the exercise session; however, participants were allowed to adjust their bikes according to their personal preferences. Cycling classes were projected onto a blank screen measuring six feet wide and eight feet tall. To ensure optimal viewing the door to the study room was closed and the lights were turned out while the video programming was playing.

Class Type

Participants were randomly assigned to participate in either an immersive, video-enhanced cycling class (IMM) or a traditional cycling class with an instructor providing audio cues for what to do (i.e., cadence, intensity, sit/stand). This latter class will be referred to as audio-only (AUD). During the IMM sessions, the only time an instructor was visible on the screen was during the bike set-up instructions. All active portions of the exercise class were narrated by an instructor not visible to study volunteers. This ensured optimal viewing of the immersive simulation. In the AUD class, the instructors were visible on the screen for the entire duration of the exercise session (from bike set-up through cool-down). Although it would be ideal to have the same instructor teaching both class formats, due to the limitations of the video programing this was not possible as no instructor teaches both the IMM class and the AUD. Both classes used similar music in which the tempo of the music was synchronized to the instructor-recommended cadence/speed of one's peddle strokes, operationally defined as revolutions per minute (RPM). Although cadence and resistance recommendations were provided by the video instructor, participants were able to self-select their desired exercise intensity via cadence and resistance modifications. In the IMM class, resistance and cadence recommendations were coordinated with the simulation and music and in the AUD class these were coordinated with the music. All classes were approximately 20 minutes in length including warmup and cooldown phases.

Health Screening

To ensure safe completion of all study procedures, participants completed the Physical Activity Readiness Questionnaire (see Appendix A) prior to study enrollment (PAR-Q+; Warburton et al., 2011). The PAR-Q+ is a brief survey consisting of a series of yes/no questions intended to identify any extant health conditions which might preclude safe participation in this study. If a participant reported "YES" to any of the items on page 1 of the PAR-Q+ they were asked to complete the additional screening questions on pages 2 and 3. If a participant answered "YES" to any items on pages 2 or 3 of the PAR-Q+ they were thanked for their interest and removed from the study. Additional screening items asked participants to report their typical weekly amount of moderate-to-vigorous activity, if they were prone to motion sickness, if they were between the ages of 18-65, if they were willing to engage in 20 minutes of self-paced cycling, and if they were comfortable wearing a heart rate monitor while exercising.

Heart Rate

Heart rate (HR) was recorded each second using short-range radio telemetry via the Polar H10 HR transmitter chest strap (Polar Electro Inc, Bethpage, NY). Heart rate data are expressed as percentage of time spent in HR zones as calculated by subtracting the participant's age from 220 (70-79% Max HR; 80-89% Max HR; 90-100% Max HR).

Survey

RPE: Ratings of perceived exertion were measured in the same manner as Oselinsky et al. (Manuscript Under Review). Immediately following the cessation of the exercise session, participants were asked to rate their exertion via a modified version of Borg's RPE Scale which was altered to assess *recalled* exertion measured immediately following the cessation of exercise (Borg, 1998). This single-item measure asked participants to "Rate how hard you had to exert yourself during the class you just completed by selecting the number that best represents your overall exertion level. Focus on your total feeling of exertion. Do not focus on just one factor (i.e., shortness of breath or leg pain)". Responses ranged from 6 (no exertion) to 20 (maximal exertion; see Appendix B). Although it would have been optimal to measure RPE *during* the exercise session, asking participants to rate how hard they are working while exercising confounds subsequent measures of attentional focus as it biases attention towards associative thinking. Additionally, as the lights were dimmed to ensure optimal viewing, the research team deemed it unsafe to interrupt the exercise session to ask participants to report their current perceptions. Therefore, in order to get the most accurate measure of attentional focus, RPE was recalled, rather than measured during the task (Graupensperger et al., 2019). This modified version of the Borg RPE scale has been found to be moderately correlated with physiological exertion (e.g., HR) and is considered both a reliable and valid measure of perceived intensity (Graupensperger et al., 2019; Haddad et al., 2017).

Enjoyment: Participants completed the Physical Activity Enjoyment Scale-8 (PACES-8; Mullen et al., 2011; Appendix B). PACES-8 is an 8-item bipolar rating scale in which participants were asked to rate their level of agreement with statements assessing enjoyment of the exercise session. Questions included "I find it pleasurable" and "It's a lot of fun". Responses were scored via a 7-point scale with opposing anchors (e.g., 1=It's no fun at all, 7=It's a lot of fun). Possible scores range from a minimum of 8 to a maximum of 56 with higher scores indicating greater enjoyment. This scale has been found to be a valid and reliable measure of PA enjoyment (Huffman et al., 2021; Mullen et al., 2011; Teques et al., 2020).

Attentional Focus: A/D was measured via a one-item survey question developed by Tammen (1996; Appendix B). Participants were asked to self-report their state of attention during the exercise session by dragging a slider along a single line to the number which best represented their overall AF. The left-most point on the line was anchored with numeric indicator of 0 and a written prompt stating "Associative: All of my thoughts during the exercise session were internally focused on things like how my body felt, breathing, cycling technique, etc.". The right-most point on the line was anchored with a numeric indicator of 100 and a written prompt stating "Dissociative: All of my thoughts during the exercise session were external thoughts, focused on things like the exercise environment (i.e., the video program, the music, other people in the room), daydreaming, my to-do list, etc.". In their original research, Tammen (1996) concluded this one-item scale is an efficient and valid measure of attentional focus (Alvarez-Alvarado et al., 2019; Tammen, 1996). Although originally designed to measure in-task A/D, research by Masters and Ogles (1998) found this single-item measure to be effective at capturing participants' in-task attentional focus immediately following exercise cessation.

Day/Time and Demographics: The day of the week and time of day that the class took place were recorded by a member of the research team. Sex assigned at birth, age, weight, and height were assessed via self-report (see Appendix B).

Procedure

Study volunteers were recruited via email or in-class announcements at the university where data collection took place. In order to participate, individuals had to be faculty, staff, or students at the university, healthy, and free of any conditions that would prevent them from safely engaging in 20-minutes of self-paced activity as indicated by their responses to the PAR-Q+ (Warburton et al., 2011). Participants must also have self-reported that they currently engage in less than 150-minutes of MVPA per week, they were not prone to motion sickness, they were between the ages of 18-65, they were comfortable wearing a heart rate monitor while exercising, and they were willing to engage in 20-minutes of self-paced activity. If a participant met the inclusion criteria, they were directed to an electronic scheduling page through which they scheduled their study session. At the start of the session, informed consent was obtained, emergency contact information was collected, participants confirmed the accuracy of their responses on the PAR-Q+ and additional screening questions (i.e., they were not prone to motion sickness, were between the ages of 18 and 65, were comfortable cycling at their own pace for 20-minutes, were comfortable wearing a HR monitor, and currently (over the past month) engage in less than 150-minutes of moderate to vigorous activity per week), and were randomly assigned to complete either the AUD class or the IMM class. Block randomization was used in instances where two study volunteers completed the exercise session at the same time. Next, the research team provided assistance with bike setup, demonstrating how to adjust each part of the bike and assisting where necessary. Following proper bike calibration, heart rate monitors were distributed with instructions provided to ensure proper placement. Heart rate monitors were worn for the duration of the exercise session. Participants were not able to see their heart rate via the study monitors. Once all participants were seated on their bikes, the lights were dimmed to ensure proper viewing of the video cycling classes. Immediately following the conclusion of the exercise session participants were asked to complete the experience survey in which they provided scores for their in-session attentional focus, RPE, and rated their level of enjoyment. Participants were also offered water at this time. Following completion of the survey, heart rate monitors were removed and collected. Once the experience survey was completed, participants received a debriefing form explaining the purpose of the study and asking that they not discuss the study with others to ensure accurate data collection from all study volunteers. Students who were eligible were awarded course credit and had the option to be entered into a drawing for 1 of 3 prizes (two $15 electronic gift cards and one $25 electronic gift card). Participants not eligible to receive course credit received $20 compensation for their participation. Subjects who were paid received payment at the end of the study after they completed all study procedures. Subjects who received course credit were given credits at the end of their participation in all study procedures. The gift card drawing occurred once data collection concluded, and the winners were notified via email.

STUDY 2 ANALYSES

A path analysis was conducted to test the study hypotheses that both RPE and enjoyment were predicted by class type indirectly via attentional focus. All variables apart from class type, which was a dichotomous variable, were scored on a continuous scale. The hypothesized path model is presented in Figure 2. All analyses were conducted in Mplus version 8.7 (Muthén & Muthén, 1998–2023). Regression coefficients, standard errors and *p*-values were reported for all paths tested. Standardized regression coefficients were used as a measure of effect size and are represented by coefficient Beta (β) in which a small effect =0.1, medium=0.3 and large=0.5. A model building approach was implemented in which only the indirect effect of class type on RPE/enjoyment through AF were estimated and model fit parameters were examined (red paths in Figure 2). In a secondary analysis, the direct effect of class type on RPE/enjoyment were included to test the tenability of the model (blue paths in Figure 2). Sample size adjusted Bayesian Information Criteria (BIC) estimates were examined to determine if this more complex model is a significant improvement over the base model. R^2 values were also examined to determine if this model explains significantly more variance in the outcomes than the base model. In all estimations, the outcome variables RPE and enjoyment were allowed to covary. Time of day was included as a covariate in the best fitting model to determine if experimental condition exerted a significant influence on AF, RPE, and exercise enjoyment after accounting for the time at which the study session was conducted.

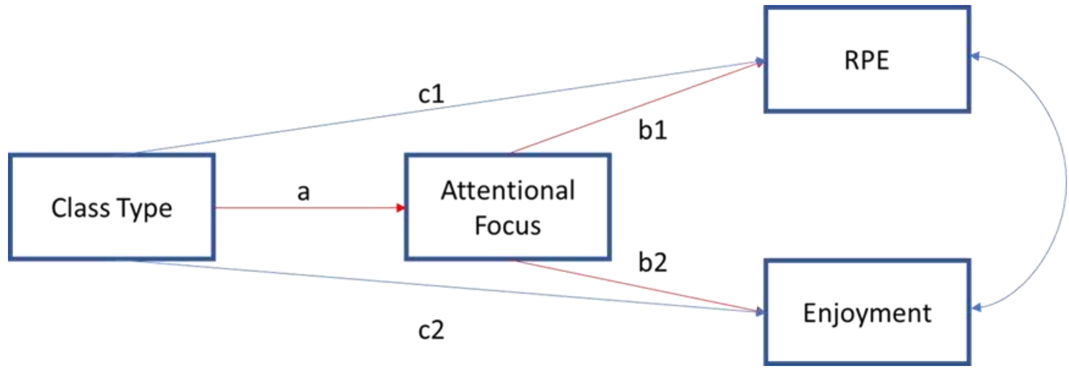

Figure 2 | Hypothesized path diagram. Class type was either an audio only cycling class or an immersive, virtual reality enhanced cycling class; RPE=ratings of perceived exertion. Red paths=indirect effects; Blue paths=direct effects; The double headed arrow indicates a hypothesized covariance between variables.

An assumption of mediation testing is that the indirect effect (a*b) is normally distributed. This is often problematic as the product of two normally distributed regression coefficients is itself non-normal. This can result in reduced statistical power when using traditional tests of mediation such as the Sobel Test. To remedy this issue, this study utilized asymmetric confidence intervals which relaxes this assumption of normality. The researchers conducted 10,000 bias-corrected bootstrap resamples and significance was achieved if the resulting 95% CI did not include zero (Efron & Tibshirani, 1993; Fritz & MacKinnon, 2007). In order to determine the effect size of the indirect effects, $P_{m,}$ which is a ratio of the indirect effect to the total effect, was utilized (Alwin & Hauser, 1975).

Model fit parameters were determined using the criteria set forth by Hu and Bentler (1999). Specifically, the research team sought to achieve a root mean square error of approximation (RMSEA) <0.06, Comparative Fit Index and Tucker Lewis Index (CFI/TLI) > 0.95, and the standardized root mean square residual (SRMR) <0.08. Finally, a non-significant Chi square test of model fit indicated good model fit.

STUDY 2 RESULTS

Overall Model Fit (Base Model; no direct effects)

The path analysis resulted in acceptable model fit. The Chi-Square test of model fit was not significant (χ^2=1.10, p= 0.58). Overall fit indices were all in the acceptable range (RMSEA = 0.00 [0.00, 0.18]; CFI = 1.00; TLI = 1.00; SRMR = 0.03).

Direct Effects

All direct effects specified in the model were non-significant. Experimental condition (IMM vs AUD) did not significantly predict AF (b = 3.59, SE = 6.02, p=0.55). A one unit increase in condition (from AUD to IMM) was associated with a 3.59 unit increase in AF (i.e., more dissociative AF) although the size of this effect was negligible (β = 0.07). AF did not significantly predict RPE (b = 0.00, SE = 0.01, p=0.86), or enjoyment (b = 0.01, SE = 0.03, p=0.69). A one unit increase in AF was therefore associated with a -0.00 unit decrease in RPE and a 0.05 unit increase in enjoyment however, both of these effects were insignificant (β = -0.02; β = 0.05). RPE negatively covaried with enjoyment however, not to a significant degree (b= -1.15, SE=1.94, p=0.55) and the effect size was trivial (β = -0.08).

Indirect Effects

Examination of the bias-corrected bootstrapped confidence intervals revealed that the specific indirect effects were not statistically significant (RPE-AF-Experimental Condition = -0.01 [-0.22, 0.08]; Enjoyment-AF-Experimental Condition = 0.05 [-0.21, 0.94]). As a path exploring the direct effect of experimental condition on RPE/enjoyment was not included in this model, no estimation of the effect size as measured via a ratio of variance explained by the indirect vs total effects (P_m) is included.

Overall Model Fit (Expanded Model; direct effects)

The expanded model which includes the direct effects relating RPE and enjoyment with experimental condition, is a saturated model. Due to this saturation, overall model fit indices are not provided.

Direct effects

All direct effects specified in this model were also non-significant. Experimental condition did not significantly predict AF, RPE, or enjoyment (b=3.59, SE=6.02, p=0.55; b=0.46, SE=0.47, p=0.33; b=0.39, SE=1.48, p=0.80). A one unit increase in condition (from AUD to IMM) resulted in a 3.59 unit increase in AF, a 0.46 unit increase in RPE, and a 0.39 unit increase in enjoyment. All of these effect sizes were small or trivial (β=0.07; β=0.11; β=0.03). As with the base model, AF did not significantly predict RPE or enjoyment (b= -0.00, SE=0.01, p=0.81; b=0.01, SE=0.03, p=0.70). Finally, as was the case in the base model, RPE and enjoyment negatively covaried but not to a significant degree (b= -1.20, SE=1.87, p=0.52, β= -0.08).

Indirect Effects

Review of the bias-corrected bootstrapped confidence intervals indicates that the indirect effects were also not statistically significant in the expanded model (RPE-AF-Experimental Condition = -0.01 [-0.24, 0.08]; Enjoyment-AF-Experimental Condition = 0.04 [-0.21, 0.93]).

The effect size of the indirect effect was examined using $P_m = ab/c$ (Alwin & Hauser, 1975), which is the ratio of the indirect effect to the total effect. This ratio can be loosely interpreted as the proportion of the total effect that is mediated. The ratio of the indirect to total effect for the Experimental Condition-AF-RPE path was P_m = -0.02, and P_m for the Experimental Condition-AF-Enjoyment was P_m= 1.00.

The P_m values obtained in this model should be interpreted with caution for several reasons. First, the estimation of Pm is unstable with less than 500 observations. Additionally, Pm becomes increasingly unstable as c' values approach 0. Both of the c' values observed in this model are all close to 0 (0.46 and 0.39) warranting further caution. It is clear however, that in both paths estimated in this model, the indirect effect is not stronger than the direct effect. Additional summary statistics are presented in Table 3 and are divided by experimental condition in Table 4. Neither model explained a significant amount of variance in the outcome variables as indicated via examination of the R^2 values (Table 5). Examination of the sample size adjusted BIC values indicated the expanded model was not an improvement over the base model (BIC=1725 and BIC=1723 respectively). Lastly, time of day was included as a covariate in the base model but was not a significant explanatory variable.

Table 3 | Summary statistics of key variables

Variable	*Mean*	*SD*	*Minimum Value*	*Maximum Value*	*Possible Range*
AF	43.61	27.50	0	100	0-100
RPE	15.08	2.15	10	20	6-20
Enjoyment	42.60	6.86	21	56	8-56
Avg HR Percent	77.36	8.83	50	96	50-100
Max HR	91.43	8.71	59	113	59-113
Time 70+	73.36	22.52	0	100	0-100

Note. SD= standard deviation; AF= attentional focus; RPE= ratings of perceived exertion; Avg HR Percent= average heart rate percent; Max HR= maximum heart rate; Time 70+ = time spent at 70% or greater of one's age determined heart rate maximum.

Table 4 | Summary statistics of key variables by experimental condition

	Audio + Immersive Video (IMM)			
Variable	*Mean*	*SD*	*Minimum Value*	*Maximum Value*
AF	45.44	27.21	0	100
RPE	15.31	1.85	11	18
Enjoyment	42.81	6.55	28	56
Avg HR Percent	79.40	8.71	58	92
Max HR	92.60	8.07	78	113
Time 70+	77.62	19.26	8	94

	Audio Only (AUD)			
Variable	*Mean*	*SD*	*Minimum Value*	*Maximum Value*
AF	41.83	27.99	0	94
RPE	14.86	2.42	10	20
Enjoyment	42.38	7.23	21	56
Avg HR Percent	75.31	8.56	50	96
Max HR	90.26	9.25	59	110
Time 70+	69.10	24.87	0	100

Note. SD= standard deviation; AF= attentional focus; RPE= ratings of perceived exertion; Avg HR Percent= average heart rate percent; Max HR= maximum heart rate; Time 70+ = time spent at 70% or greater of one's age determined heart rate maximum.

Table 5 | R^2 estimates for the outcome and proposed mediator variables in the base and expanded models

	Base Model (no direct effects)		
Variable	*Estimate*	*SE*	*p-value*
AF	0.004	0.023	0.848
Enjoyment	0.002	0.023	0.915
RPE	0.000	0.020	0.982

	Expanded Model (direct effects)		
Variable	*Estimate*	*SE*	*p-value*
AF	0.004	0.022	0.848
Enjoyment	0.003	0.029	0.909
RPE	0.012	0.034	0.723

Note. SE= standard error; AF= attentional focus; RPE= ratings of perceived exertion.

Post-hoc Exploratory Analyses

Post-hoc exploratory *t*-tests were conducted to determine if time spent working at 70% or greater of one's age determined HR maximum and average HR percent were significantly different between experimental conditions. An additional path analysis was conducted in which participating alone or in a pair was included as a covariate in the model. Analyses were conducted in 2023 using RStudio Statistical Software version 2022.12.0 (RStudio Team, 2023) and Mplus version 8.7 (Muthén & Muthén, 2107). Independent samples *t*-tests were used to determine the impact of class type (traditional audio only [AUD] vs immersive video enhanced [IMM]) on participants' time spent at 70% or greater of their age determine HR maximum and average HR percent. Alpha was set at $p < 0.05$ for all analyses. A Shapiro Test for normality indicated that time spent at 70% or greater of one's age determine HR maximum did not conform to a normal distribution ($p < 0.05$). Due to this non-normality, the researchers opted to conduct the non-parametric Wilcoxon test when assessing this variable. Results of the Wilcoxon and *t*-tests indicated time spent in a moderate to vigorous HR zone ($p<0.05$, 95% CI [-12.00, -0.00]) and average HR percent were significantly greater in the IMM condition than in the AUD condition ($p<0.05$, 95% CI [-7.84, -0.35]; Figure 3). Both of these differences resulted in small to moderate effect sizes (d=0.39; d=0.48). Results of the path analysis indicated there was a beneficial effect of exercising with others on RPE as evidenced by a 1.034 unit decrease in RPE when completing the study session in a pair compared to alone ($p<0.05$, 95% CI [-2.08, -0.09], $\beta = -0.23$). Participating in a pair versus alone did not exert a significant influence on any other variables included in the model.

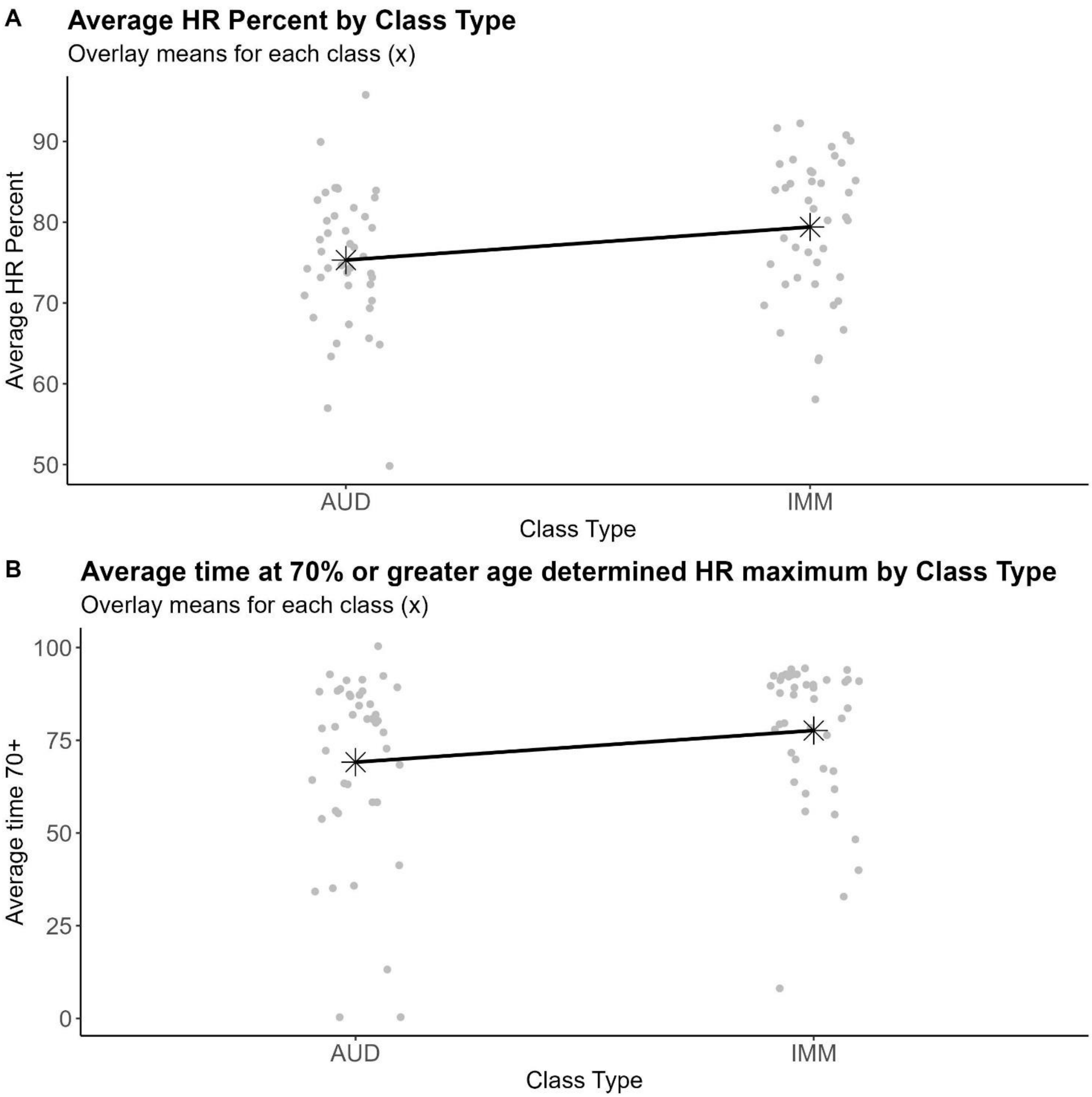

Figure 3 | Heart rate data by class type. HR= heart rate; AUD=audio only cycling class; IMM= immersive, virtual reality enhanced cycling class; Average time 70+ = average time spent working at 70% or greater of one's age determined maximum heart rate.

STUDY 2 DISCUSSION

This study sought to determine if AF mediates the relationship between immersive VR technology and RPE/enjoyment during an exercise session. Contrary to our hypotheses, AF did not mediate the relationship between the presence of immersive VR technology, and RPE or enjoyment during an exercise session, and RPE was not significantly correlated with enjoyment. The results of this study diverge from the extant literature which suggests AF is the mechanism through which immersive technology exerts a significant influence on RPE and exercise enjoyment (Mestre, et al., 2011; Mouatt et al., 2020; Murray et al., 2016). Additionally, several other studies which have explored the relationships between the aforementioned variables found significant impacts of immersive technology on perceptions of exertion and overall exercise enjoyment (Bird et al., 2019, 2021; Chow & Etnier, 2017; Oselinsky et al., Manuscript Under Review). Those findings were not replicated here as the direct effects of experimental condition on the outcome variables were also non-significant. An unexpected finding revealed during post-hoc exploratory analyses was that within this sample, time spent at 70% or greater of one's age determined HR maximum and average HR percent were significantly greater in the immersive condition than in the audio only and both of these differences demonstrated small to moderate effects.

Closer examination of the descriptive statistics revealed that in both conditions' enjoyment was high (AUD=42.38; IMM=42.81), and on average most participants spent a substantial amount of time during the experimental sessions working at 70% or greater of their maximum HR (AUD=69.10%; IMM=77.62%). In thinking about why the experimental conditions elicited high levels of enjoyment it is possible that both video stimuli presented a novel and exciting departure from normal work activities for the participants. Data for this study were collected at a large western U.S. university. In order to enroll, participants must have been faculty, staff, or students at the university where data collection took place. The majority of the participants enrolled were faculty or staff (78%) and a majority of the sessions occurred during the workday (i.e., 80% of the sessions occurred on Monday-Friday from 8am-6:30pm). It is possible that participating in this study provided an exciting departure from the routine of a typical workday and was therefore viewed favorably by most participants, regardless of experimental condition. If this study had been conducted longitudinally, allowing the novelty of the exercise session to subside, results might have looked more similar to those found in the extant literature in which a beneficial impact of immersive technology on the exercise experience has been observed (Bigliassi et al., 2019; Chow & Etnier, 2017; Gillman & Bryan, 2016; Hutchinson et al., 2015, 2017; Jones et al., 2014; Jones & Ekkekakis, 2019; Oselinsky et al., Manuscript Under Review; Stewart et al., 2022). Additionally, it is possible the AUD condition elicited a dissociative effect providing affective benefits due to the lively banter and enthusiastic attitudes of the class instructors. The video instructor's joyful response to the exercise session and copious use of motivation and encouragement might have led to an overall more positive experience than if a blander stimulus (i.e., a video which does not incorporate as much interaction between or feedback from instructors) had been presented in the AUD condition.

An unexpected finding in this study was that actual exertion (as indicated via HR) was greater in the IMM condition; however, levels of enjoyment and perceived exertion did not differ between conditions. This indicates participants worked harder but were not aware of this increased effort during the immersive cycling sessions. Research by Oselinsky et al. (Manuscript Under Review) found a similar effect when integrating immersive technology into a cycling session. In their study, the authors found that although AF did not differ based on the presence of immersive technology, RPE was significantly lower and enjoyment was significantly higher when cycling while viewing an immersive VR simulation. Importantly, actual exertion was the same regardless of the VR technology. This indicates that the participants felt like they were not working as hard and enjoyed the immersive exercise session more than an audio-only class while still exercising at an intensity sufficient to induce desirable health consequences (Oselinsky et al., Manuscript Under Review). Together, the results of these studies support an advantageous disconnect people experience when exercising while viewing an immersive VR simulation. These studies suggest that integrating immersive technology into exercise settings can lead people to enjoy harder efforts more than they would in traditional exercise settings. A final, albeit unsurprising finding revealed in the post-hoc exploratory analyses was the beneficial effect of exercising in pairs on RPE. A large body of research suggests exercising in groups has additional benefits such as increasing motivation, commitment, exertion, and produces greater mood enhancements than when exercising alone (Andersson & Christakis, 2016; Feltz et al., 2011; Irwin et al., 2012; Plante, 2010; Stevens et al., 2021; Wing & Jeffery, 1999; Yorks et al., 2017).

Although AF did not significantly differ between experimental conditions in this study, it is possible the single-item measure used to assess AF failed to appropriately capture participants' levels of associative and dissociative thinking. While found to be a valid and reliable assessment of recalled AF (Masters & Ogles, 1998; Tammen, 1996), this single-item measure has been criticized as being overly simplistic, with skeptics saying it fails to capture other relevant dimensions of attention such as direction (i.e., internal vs external, Brick et al., 2014; Wininger & Gieske, 2010). Additionally, assessing recalled AF is notoriously challenging as it relies on accurate metacognitive awareness. Before being dismissed as a mediator relating immersive technology to RPE/exercise enjoyment, more work is needed to definitively determine the impact of AF.

If AF truly does not explain how immersive technology exerts a beneficial influence on the exercise experience, other potential causal mechanisms should be examined. Two possible mechanisms that are related to AF but different constructs, are sense of immersion and presence. In VR, immersion is defined as "the degree to which the range of sensory channels is engaged by the virtual simulation" (Kim & Biocca, 2018, p. 95). Presence is defined as one's sense of being in the virtual world. What makes presence distinct from AF is that presence is a perceptual, not a cognitive experience. It is only after the perceptual system is activated that one's cognition begins to identify what they are experiencing is an illusion (Berkman & Akan, 2019). It is possible the VR simulation used in this study elicited higher levels of immersion and presence, temporarily drawing participants into the fictional world depicted by the video simulation. Feeling as though they were really cycling on the futuristic racetrack portrayed in the video (Figure 4) might have led to a dampening of physiological sensations which could explain why actual but not perceived exertion was greater in the immersive condition.

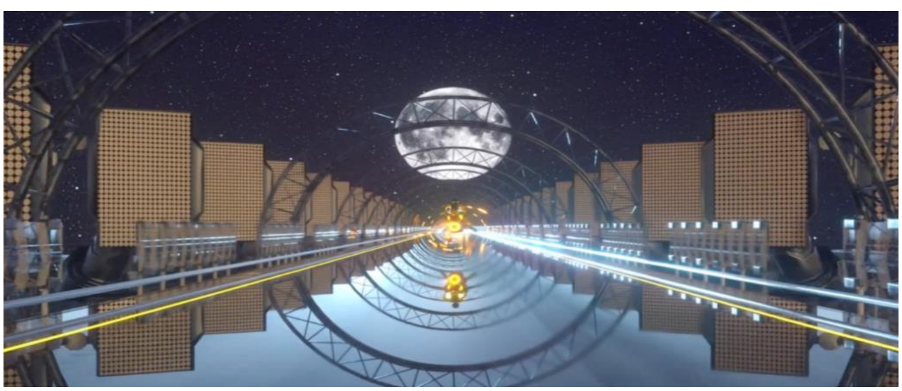

Figure 4 | Sample image of racetrack displayed in the immersive, virtual reality enhanced cycling condition.

Strengths

Although the hypotheses were not supported, this study has several strengths. First, this study is the only study of which the authors are aware that directly tested the theoretically supported causal pathway relating immersive technologies to RPE/enjoyment through AF. This was done using a strong empirical design in which participants were randomly assigned to one of two experimental conditions of empirical interest (AUD vs IMM). The research assistants who interacted with the participants were provided a script from which they did not deviate reducing the chances of experimenter bias having impacted the study results. Additionally, the study volunteers were individuals who are currently insufficiently active, a population of substantial scientific and public health interest.

All of the measures included in the study have been shown to be valid and reliable indicators of the constructs they intend to assess. This increases confidence in the findings as researchers can be certain the variables in this study were measured appropriately and the results accurately reflect the identified constructs. The participants in this study were diverse in terms of age (Mean=28.70 years, *SD*=10.16, Range=18-64) and health status (BMI=24.04, *SD*=5.14, Range=13.02-37.97), resulting in greater generalizability of the results. Lastly, this study was conducted in a university research laboratory allowing for maximum research control. In this way, the research team was able to increase the accuracy of participant responses by ensuring all study volunteers completed the experience survey immediately following the cessation of the exercise session, and that all participants were able to complete the survey in a quiet room, free of any distractions which might impact their survey responses.

Limitations

Although an a-priori power analysis indicated a sample of 75 participants would be sufficient to detect mediation, it is possible the effect sizes for the a and b-paths were overestimated resulting in an inaccurate sample size calculation. Due to the small effect sizes observed in this study, it is likely the sample obtained was insufficiently large and therefore the research team was underpowered to detect mediation. Additionally, this study used post-tasks measures rather than in-task measures to assess the key constructs. While it would have been ideal to measure AF, RPE, and enjoyment during the exercise session, due to the safety consideration within the experimental environment in which the lights were off to create a more immersive experience, and the possible confounding effects of asking participants to report their in-task RPEs thereby biasing attention towards association, the research team opted to use post-task measures.

As previously alluded to, the audio-only class may have confounded the results due to its appealing nature and novel presentation. The video presented four instructors on screen all of whom wore bright colors and included background lighting which shifted subtly throughout the video class. Additionally, the instructors in this video interacted with each other and with fitness class participants who were in the room when the video was filmed (although these individuals were not visible in the video). The instructors often engaged in lively banter and provided ample words of motivation and encouragement. Furthermore, research indicates the presentation of a novel stimuli, such as the video used in this study, can draw attention outward which might have resulted in a more dissociative AF than if the video had been familiar (Cleary et al., 2023). It is likely that, collectively, these elements were enough to distract participants' attention away from adverse bodily sensations while concurrently increasing enjoyment of the exercise session. A different audio-only stimulus in which no video elements were presented may have elicited a starkly different response from the study volunteers. Lastly, this study was conducted in an area that has high population levels of physical activity. As the area in which the study was conducted has high rates of PA, it is likely the majority of the participants were overall more active than insufficiently active individuals from other areas of the country. Finally, it is possible those who participated already had positive perceptions of PA as indicated by their willingness to participate in a cycling study.

Future Directions

Future research should seek to expand the number of exercise sessions for each participant. It is possible immersive technologies may be effective at altering perceptions of the exercise experience by varying AF, however, this effect may not be apparent after only one exercise session. Additional sessions will allow the novelty effect of the video programming to diminish enabling deeper examination of the research questions. Additionally, future research should strive to identify what distracting elements are actually required/effective at inducing a dissociative state. The results of this study indicate immersive VR might not be necessary if the goal is to produce greater exercise enjoyment and lower RPEs. Rather, engaging instructors may be sufficient to elicit a beneficial effect. Further, research indicates simple dissociative tactics such as mind-wandering can lead to mood enhancements, underscoring the importance of continued research regarding what stimuli are required to induce positive perceptions of the exercise experience (Miś & Kowalczyk, 2021). Lastly, as AF was not found to mediate the relationship between immersive technology and RPE/enjoyment, future studies should strive to identify other potential mediators, such as immersion and presence, which explain *how* immersive VR technology impacts exercise perceptions.

Conclusions

This study found that AF does not mediate the relationship between immersive VR technology and RPE/exercise enjoyment. Before there is additional investment in the development and incorporation of these technologies into fitness settings, more research is needed to determine how technology affects individuals' perceptions of exercise. Additionally, a more detailed examination of what is required to elicit a dissociative AF during an exercise session is warranted as this study indicates, less cost-prohibitive methods such as engaging instructors may be all that is required to create a favorable exerciser response.

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APPENDIX A

PAR-Q+ AND ADDITIONAL SCREENING QUESTIONS

Thank you so much for your interest in this study! This research involves the use of a novel immersive, virtual reality simulation displayed while riding a stationary exercise bike. Although this study presents minimal risk, we want to make sure this is a comfortable and fun experience for everyone who participates.

To make sure this will be a positive experience for you, please answer the following questions honestly and to the best of your ability.

Are you prone to motion sickness?

○ YES

○ NO

Are you between the ages of 18-65?

○ YES

○ NO

Are you comfortable wearing a heart rate monitor while exercising?

○ YES

○ NO

Are you willing to participate in 20-minutes of self-paced stationary cycling?

○ YES

○ NO

Do you currently (i.e., over the past month) engage in **more** than 150 minutes of self-paced activity per week?

By this we mean you engage in less than 150-mintutes of moderate to vigorous intensity exercise per week. Moderate-intensity physical activity means you're working hard enough to raise your heart rate and break a sweat. One way to tell if it's a moderate-intensity activity is that you'll be able to talk, but not sing the words to your favorite song. Vigorous-intensity activity means you're breathing hard and fast, and your heart rate has gone up quite a bit. If you're being active at a vigorous level, you won't be able to say more than a few words without pausing for a breath. Activities like participating in group fitness classes, playing a sport, running, cycling, etc. would all be considered moderate to vigorous intensity activities.

○ YES

○ NO

Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before participating in this study.

Please read the following 7 questions carefully and answer each one honestly.

Has your doctor ever said that you have a heart condition OR high blood pressure?

- ◯ YES
- ◯ NO

Do you feel pain in your chest at rest, during your daily activities of living, OR when you do physical activity?

- ◯ YES
- ◯ NO

Do you lose balance because of dizziness OR have you lost consciousness in the last 12 months? *Please answer NO if your dizziness was associated with over-breathing (including during vigorous exercise).

- ◯ YES
- ◯ NO

Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)?

- ◯ YES (please list condition(s) here) ______________________________

- ◯ NO

Are you currently taking prescribed medications for a chronic medical condition?

◯ YES (please list medication here)

____

◯ NO

Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active?
*Please answer NO if you had a problem in the past, but it does not limit your current ability to be physically active.

◯ YES (Please list condition(s) here)

____

◯ NO

Has your doctor ever said that you should only do medically supervised physical activity?

◯ YES

◯ NO

Based on your responses to the previous health screening questions, we have a few follow up questions.

Do you have Arthritis, Osteoporosis, or Back Problems?

◯ YES

◯ NO

Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)

◯ YES

◯ NO

Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?

◯ YES

◯ NO

Have you had steroid injections or taken steroid tablets regularly for more than 3 months?

◯ YES

◯ NO

Do you currently have Cancer of any kind?

○ YES

○ NO

Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and/or neck?

○ YES

○ NO

Are you currently receiving cancer therapy (such as chemotherapy or radiotherapy)?

○ YES

○ NO

Do you have a Heart or Cardiovascular Condition? This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm

○ YES

○ NO

Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)

○ YES

○ NO

Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction)

○ YES

○ NO

Do you have chronic heart failure?

○ YES

○ NO

Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?

○ YES

○ NO

Do you currently have High Blood Pressure?

○ YES

○ NO

Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)

○ YES

○ NO

Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer YES if you do not know your resting blood pressure)

○ YES

○ NO

Do you have any Metabolic Conditions? This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes

○ YES

○ NO

Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician prescribed therapies?

◯ YES

◯ NO

Do you often suffer from signs and symptoms of low blood sugar (hypoglycemia) following exercise and/or during activities of daily living? Signs of hypoglycemia may include shakiness, nervousness, unusual irritability, abnormal sweating, dizziness or light-headedness, mental confusion, difficulty speaking, weakness, or sleepiness.

◯ YES

◯ NO

Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, OR the sensation in your toes and feet?

◯ YES

◯ NO

Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)?

◯ YES

◯ NO

Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future?

○ YES

○ NO

Do you have any Mental Health Problems or Learning Difficulties? This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome.

○ YES

○ NO

Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)

○ YES

○ NO

Do you have Down Syndrome AND back problems affecting nerves or muscles?

○ YES

○ NO

Do you have a Respiratory Disease? This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure.

○ YES

○ NO

Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)

- ◯ YES
- ◯ NO

Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?

- ◯ YES
- ◯ NO

If asthmatic, do you currently have symptoms of chest tightness, wheezing, labored breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?

- ◯ YES
- ◯ NO

Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?

- ◯ YES
- ◯ NO

Do you have a Spinal Cord Injury? This includes Tetraplegia and Paraplegia

○ YES

○ NO

Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)

○ YES

○ NO

Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?

○ YES

○ NO

Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?

○ YES

○ NO

Have you had a Stroke? This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event.

○ YES

○ NO

Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)

○ YES

○ NO

Do you have any impairment in walking or mobility?

○ YES

○ NO

Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?

○ YES

○ NO

Do you have any other medical condition not listed above or do you have two or more medical conditions?

○ YES

○ NO

Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months OR have you had a diagnosed concussion within the last 12 months?

○ YES

○ NO

Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?

○ YES

○ NO

Do you currently live with two or more medical conditions?

○ YES (Please list your medical condition(s) and any related medications)

____

○ NO

APPENDIX B

TO BE FILLED OUT BY A MEMBER OF THE RESEARCH TEAM

1. Participant ID: ___________________
2. Experimental Condition: Condition Zero (0):________ Condition One (1): _________
3. Day of the Week: __________________
4. Time of day (e.g., 9:30am, 1:00pm etc.):______________________

Post-exercise Experience Survey

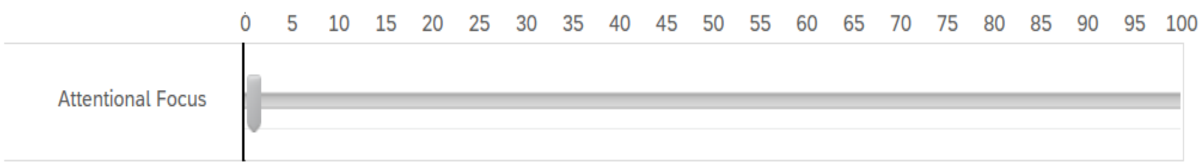
The following questions are intended to assess your experience of the cycling session you just completed. Your answers are anonymous, so please answer honestly and to the best of your ability. Please direct all questions about this survey to a member of the study team.

1. Estimate your state of attention during the exercise session by dragging the slider to the corresponding value.

   0= Associative: All of my thoughts during the exercise session were internally focused on things like how my body felt, breathing, cycling technique, etc.

   50= Equal: About half my thoughts were focused inward and about half my thoughts were focused externally

   100= Dissociative: All of my thoughts during the exercise session were external thoughts, focused on things like the exercise environment (i.e., the video program, the music, other people in the room), daydreaming, my to-list, etc.



2. Rate your enjoyment with the class by circling the number that best represents your level of enjoyment.

Not at all enjoyable				Somewhat enjoyable				Extremely enjoyable	
1	2	3	4	5	6	7	8	9	10

6	No effort at all (REST)
7	Very Very Light
8	
9	Very Light
10	
11	Fairly Light
12	
13	Somewhat Hard
14	
15	Hard
16	
17	Very Hard
18	
19	Very Very Hard
20	Maximal Effort

3. Rate how hard you had to exert yourself during the **class you just completed** by circling the number that best represents your **overall exertion level**. Focus on your **total feeling** of exertion. Do **not** focus on just one factor (i.e., shortness of breath or leg pain)

Exertion	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

4. Please indicate how you feel at the moment about the physical activity you have been doing by circling the number which best corresponds to your current feelings.

It was very unpleasant						It was very pleasant
1	2	3	4	5	6	7

I found it unpleasurable						I found it pleasurable
1	2	3	4	5	6	7

It was no fun at all						It was a lot of fun
1	2	3	4	5	6	7

It was not at all invigorating						It was very invigorating
1	2	3	4	5	6	7

It was not at all gratifying						It was very gratifying
1	2	3	4	5	6	7

It was not at all exhilarating						It was very exhilarating
1	2	3	4	5	6	7

It was not at all stimulating						It was very stimulating
1	2	3	4	5	6	7

It was not at all refreshing						It was very refreshing
1	2	3	4	5	6	7

5. Rate how you felt during the exercise session. Record your responses by circling the number which best represents how you felt during the exercise session.

Very bad					Neutral					Very good
-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
		Bad		Fairly Bad		Fairly Good		Good		

6. Please use the following scale to indicate the extent to which each word below describes how you feel about the exercise session you just completed. Record your responses by filling in the circle corresponding to the appropriate value.

	Do not feel	Feel slightly	Feel moderately	Feel strongly	Feel very strongly
Upbeat	○	○	○	○	○
Calm	○	○	○	○	○
Energetic	○	○	○	○	○
Tired	○	○	○	○	○
Peaceful	○	○	○	○	○
Miserable	○	○	○	○	○
Worn-out	○	○	○	○	○
Relaxed	○	○	○	○	○
Fatigued	○	○	○	○	○
Discouraged	○	○	○	○	○

7. Please circle the number which best represents how frequently you focused on thoughts from each of the below categories during the cycling session.

1) Active Self-Regulation

0	1	2	3	4	5	6	7	8	9	10
Never	Almost never	Rarely	Seldom	Sometimes	Occasionally	Often	Frequently	Most of the time	Almost always	Always

- Pacing and tactics
- Relaxing
- Chunking
- Self-talk/mantras
- Improving technique

- Improving cadence/rhythm
- Mindfulness
- Objective/targets

- Imagery/visualization
- Counting
- Meditation
- Other______________

2) Internal Sensory Monitoring

0	1	2	3	4	5	6	7	8	9	10
Never	Almost never	Rarely	Seldom	Sometimes	Occasionally	Often	Frequently	Most of the time	Almost always	Always

- Body movement
- Exertional pain
- Muscle Soreness
- Fatigue

- Breathing
- Temperature
- Thirst
- Perspiration

- Overall effort/feel
- Heart rate
- Injury
- Other:______________________

3) Outward Monitoring

0	1	2	3	4	5	6	7	8	9	10
Never	Almost never	Rarely	Seldom	Sometimes	Occasionally	Often	Frequently	Most of the time	Almost always	Always

- Bicycle noise
- Wheel speed
- Time (i.e., focused on the clock)

- Lab conditions (e.g., temperature of the room)
- Other:________________

4) Distraction

0	1	2	3	4	5	6	7	8	9	10
Never	Almost never	Rarely	Seldom	Sometimes	Occasionally	Often	Frequently	Most of the time	Almost always	Always

- Intentionally switching off
- Video programming
- Music

- Reflective thoughts
- Other people in the lab
- Irrelevant daydreams
- Other: ________________

8. The following questions are about your experience with the video programming. Circle the number which best represents your experience with the video programming. Please answer honestly and to the best of your ability.

To what extent did you feel it was necessary to devote all your attention to what you were doing in the video world?

Not at all					Somewhat					A great deal
0	1	2	3	4	5	6	7	8	9	10

To what extent did you feel like you "went into" the video world and you almost forgot about the world outside?

Not at all					Somewhat					A great deal
0	1	2	3	4	5	6	7	8	9	10

To what extent did you have to pay excessive attention to what was going on in the video world?

Not at all					Somewhat					A great deal
0	1	2	3	4	5	6	7	8	9	10

To what extent did you forget you were in a room at CSU?

Not at all					Somewhat					A great deal
0	1	2	3	4	5	6	7	8	9	10

9. The following items are additional questions about your experience with the video programming. Record your responses by filling in the circle corresponding to the appropriate value. Please answer honestly and to the best of your ability.

When the video ended, I felt like I came back to the "real world" after a journey.

○	○	○	○	○	○	○
Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree

The video created a new world for me and the world suddenly disappeared when the video ended.

○	○	○	○	○	○	○
Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree

During the cycling session, I felt I was in the world the video created.

○	○	○	○	○	○	○
Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree

During the cycling session, I NEVER forgot that I was in the middle of an experiment.

○	○	○	○	○	○	○
Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree

During the cycling session, my body was in the room, but my mind was inside the world created by video.

○	○	○	○	○	○	○
Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree

During the cycling session, the video-generated world was more real or present for me compared to the “real world.”

○	○	○	○	○	○	○
Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree

The video-generated world seemed to me only “something I saw” rather than “somewhere I visited.”

○	○	○	○	○	○	○
Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree

During the cycling session, my mind was in the room, not in the world created by video.

○	○	○	○	○	○	○
Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree

10. For **last night**, how would you rate your sleep quality overall? Record your responses by filling in the circle corresponding to the appropriate value.

○	○	○	○	○
Very bad	Fairly bad	About average	Fairly good	Very good

11. What time did you go to sleep last night?

____

12. What time did you wake up this morning?

____

13. The following questions ask about your typical experience of mind wandering. Mind wandering refers to the occurrence of thoughts that are not related to a given task at hand.

For the following statements please select the answer that most accurately reflects your everyday mind wandering. Record your responses by circling the number which best corresponds to your everyday experiences of mind wandering.

I find my thoughts wandering spontaneously.

Rarely						A lot
1	2	3	4	5	6	7

When I mind-wander, my thoughts tend to be pulled from topic to topic.

Rarely						A lot
1	2	3	4	5	6	7

It feels like I don't have control over when my mind wanders.

Not at all true						Very True
1	2	3	4	5	6	7

I mind-wander even when I am supposed to be doing something else.

Rarely						A lot
1	2	3	4	5	6	7

I allow my thoughts to wander on purpose.

Rarely						A lot
1	2	3	4	5	6	7

I enjoy mind-wandering.

Rarely						A lot
1	2	3	4	5	6	7

I find mind-wandering is a good way to cope with boredom.

Not at all true						Very True
1	2	3	4	5	6	7

I allow myself to get absorbed in pleasant fantasy.

Rarely						A lot
1	2	3	4	5	6	7

14. Please rate each of the following statements using the scale provided. Record your responses by filling in the circle that best describes your own opinion of what is generally true for you.

I pay attention to sensations, such as the wind in my hair or sun on my face.

○	○	○	○	○
Never or very rarely true	Rarely true	Sometimes true	Often true	Very often or always true

I pay attention to sounds, such as clocks ticking, birds chirping, or cars passing.

○	○	○	○	○
Never or very rarely true	Rarely true	Sometimes true	Often true	Very often or always true

I notice the smells and aromas of things.

○	○	○	○	○
Never or very rarely true	Rarely true	Sometimes true	Often true	Very often or always true

I notice visual elements in art or nature, such as colors, shapes, textures, or patterns of light and shadow.

◯	◯	◯	◯	◯
Never or very rarely true	Rarely true	Sometimes true	Often true	Very often or always true

I can easily put my beliefs, opinions, and expectations into words.

◯	◯	◯	◯	◯
Never or very rarely true	Rarely true	Sometimes true	Often true	Very often or always true

It's hard for me to find the words to describe what I'm thinking.

◯	◯	◯	◯	◯
Never or very rarely true	Rarely true	Sometimes true	Often true	Very often or always true

I have trouble thinking of the right words to express how I feel about things.

◯	◯	◯	◯	◯
Never or very rarely true	Rarely true	Sometimes true	Often true	Very often or always true

I can usually describe how I feel at the moment in considerable detail.

◯	◯	◯	◯	◯
Never or very rarely true	Rarely true	Sometimes true	Often true	Very often or always true

When I do things, my mind wanders off and I'm easily distracted.

◯	◯	◯	◯	◯
Never or very rarely true	Rarely true	Sometimes true	Often true	Very often or always true

I am easily distracted.

◯	◯	◯	◯	◯
Never or very rarely true	Rarely true	Sometimes true	Often true	Very often or always true

I find it difficult to stay focused on what's happening in the present.

◯	◯	◯	◯	◯
Never or very rarely true	Rarely true	Sometimes true	Often true	Very often or always true

I find myself doing things without paying attention.

◯	◯	◯	◯	◯
Never or very rarely true	Rarely true	Sometimes true	Often true	Very often or always true

I tell myself that I shouldn't be thinking the way I'm thinking.

◯	◯	◯	◯	◯
Never or very rarely true	Rarely true	Sometimes true	Often true	Very often or always true

I think some of my emotions are bad or inappropriate and I shouldn't feel them.

◯	◯	◯	◯	◯
Never or very rarely true	Rarely true	Sometimes true	Often true	Very often or always true

When I have distressing thoughts or images, I judge myself as good or bad, depending what the thought/image is about.

◯	◯	◯	◯	◯
Never or very rarely true	Rarely true	Sometimes true	Often true	Very often or always true

I disapprove of myself when I have irrational ideas.

◯	◯	◯	◯	◯
Never or very rarely true	Rarely true	Sometimes true	Often true	Very often or always true

I watch my feelings without getting lost in them.

◯	◯	◯	◯	◯
Never or very rarely true	Rarely true	Sometimes true	Often true	Very often or always true

When I have distressing thoughts or images, I "step back" and am aware of the thought or image without getting taken over by it.

◯	◯	◯	◯	◯
Never or very rarely true	Rarely true	Sometimes true	Often true	Very often or always true

When I have distressing thoughts or images, I feel calm soon after.

◯	◯	◯	◯	◯
Never or very rarely true	Rarely true	Sometimes true	Often true	Very often or always true

When I have distressing thoughts or images, I just notice them and let them go.

◯	◯	◯	◯	◯
Never or very rarely true	Rarely true	Sometimes true	Often true	Very often or always true

15. Below is a collection of statements about your everyday experiences. Please indicate how frequently or infrequently you currently have each experience by filling in the circle corresponding to the appropriate value. Please answer according to what really reflects your experience rather than what you think your experience should be. Please treat each item separately from every other item.

I could be experiencing some emotion and not be conscious of it until sometime later.

◯	◯	◯	◯	◯	◯
Almost never	Very infrequently	Somewhat infrequently	Somewhat frequently	Very frequently	Almost always

I break or spill things because of carelessness, not paying attention, or thinking of something else.

◯	◯	◯	◯	◯	◯
Almost never	Very infrequently	Somewhat infrequently	Somewhat frequently	Very frequently	Almost always

I find it difficult to stay focused on what's happening in the present.

◯	◯	◯	◯	◯	◯
Almost never	Very infrequently	Somewhat infrequently	Somewhat frequently	Very frequently	Almost always

I tend to walk quickly to get where I'm going without paying attention to what I experience along the way.

◯	◯	◯	◯	◯	◯
Almost never	Very infrequently	Somewhat infrequently	Somewhat frequently	Very frequently	Almost always

I tend not to notice feelings of physical tension or discomfort until they really grab my attention.

◯	◯	◯	◯	◯	◯
Almost never	Very infrequently	Somewhat infrequently	Somewhat frequently	Very frequently	Almost always

I forget a person's name almost as soon as I've been told it for the first time.

◯	◯	◯	◯	◯	◯
Almost never	Very infrequently	Somewhat infrequently	Somewhat frequently	Very frequently	Almost always

It seems I am "running on automatic," without much awareness of what I'm doing.

◯	◯	◯	◯	◯	◯
Almost never	Very infrequently	Somewhat infrequently	Somewhat frequently	Very frequently	Almost always

I rush through activities without being really attentive to them.

◯	◯	◯	◯	◯	◯
Almost never	Very infrequently	Somewhat infrequently	Somewhat frequently	Very frequently	Almost always

I get so focused on the goal I want to achieve that I lose touch with what I'm doing right now to get there.

◯	◯	◯	◯	◯	◯
Almost never	Very infrequently	Somewhat infrequently	Somewhat frequently	Very frequently	Almost always

I do jobs or tasks automatically, without being aware of what I'm doing.

◯	◯	◯	◯	◯	◯
Almost never	Very infrequently	Somewhat infrequently	Somewhat frequently	Very frequently	Almost always

I find myself listening to someone with one ear, while doing something else at the same time.

◯	◯	◯	◯	◯	◯
Almost never	Very infrequently	Somewhat infrequently	Somewhat frequently	Very frequently	Almost always

I drive places on 'automatic pilot' and then wonder why I went there.

◯	◯	◯	◯	◯	◯
Almost never	Very infrequently	Somewhat infrequently	Somewhat frequently	Very frequently	Almost always

I find myself preoccupied with the future or the past.

◯	◯	◯	◯	◯	◯
Almost never	Very infrequently	Somewhat infrequently	Somewhat frequently	Very frequently	Almost always

I find myself doing things without paying attention.

◯	◯	◯	◯	◯	◯
Almost never	Very infrequently	Somewhat infrequently	Somewhat frequently	Very frequently	Almost always

I snack without being aware that I'm eating.

◯	◯	◯	◯	◯	◯
Almost never	Very infrequently	Somewhat infrequently	Somewhat frequently	Very frequently	Almost always

16. What is your race?

- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Pacific Islander
- ☐ White
- ☐ Unknown/unidentified/other
- ☐ Prefer not to answer

17. What is your ethnicity?

- ○ Hispanic or Latino
- ○ Not Hispanic or Latino
- ○ Prefer not to answer

18. What is your gender?

- ○ Female
- ○ Male
- ○ Non-binary/third gender
- ○ Other/unidentified
- ○ Prefer not to answer

19. What was your sex assigned at birth?

- ○ Male
- ○ Female
- ○ Prefer not to say

20. How tall are you (i.e., 6 feet 2 inches or 5 feet 8 inches, etc.)?

____

21. How much do you weight (in pounds)

____

22. How old are you (in years)

____