Perceptual responses to high- and moderate-intensity interval exercise in adolescents

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ABSTRACT

Purpose: High-intensity continuous exercise is proposed to evoke unpleasant sensations as predicted by the dual mode theory (DMT), and may negatively impact on future exercise adherence. Previous studies support unpleasant sensations in affective responses during continuous high-intensity exercise, but the affect experience during high-intensity interval exercise (HIIE) involving brief bursts of high-intensity exercise separated by low-intensity activity is poorly understood in adolescents. We examined the acute affective, enjoyment and perceived exertion responses to HIIE compared to moderate-intensity interval exercise (MIIE) in adolescents. **Methods**: Thirteen adolescent boys (mean±SD; age 14.0±0.5 years) performed two counterbalanced exercise conditions: 1) HIIE: 8 x 1-minute work intervals at 90% maximal aerobic speed; and 2) MIIE: between 9-12 x 1-minute work intervals at 90% ventilatory threshold where the number of intervals performed were distance-matched to HIIE. HIIE and MIIE intervals were interspersed with 75 s active recovery at 4 $km \cdot h^{-1}$. Affect, enjoyment and rating of perceived exertion (RPE) were recorded before, during and after exercise. **Results**: Affect responses declined in both conditions but the fall was greater in HIIE than MIIE (P<0.025, ES=0.64 to 0.81). Affect remained positive at the end work-interval for both conditions (MIIE= 2.62±1.50; HIIE= 1.15±2.08 on feeling scale). No enjoyment differences were evident during HIIE and MIIE (P=0.32), but HIIE elicited greater post-exercise enjoyment compared to MIIE (P=0.01, ES=0.47). RPE was significantly higher during HIIE than MIIE across all work-intervals (all P<0.03, ES>0.64). **Conclusions**: Despite elevated RPE, HIIE did not elicit prominent unpleasant feelings as predicted by DMT and was associated with greater post-exercise enjoyment responses than MIIE. This study demonstrates the feasibility of the application of HIIE as an alternative form of PA in adolescents.

Key Words: Affective valence, exercise enjoyment, feasibility, interval exercise, youth

INTRODUCTION

High-intensity interval exercise (HIIE) has been shown to improve cardiorespiratory fitness and cardiometabolic health in adolescents (1). Given that low levels of physical activity (PA) in youth are evident (2), HIIE has emerged as a strategy to engage adolescents in PA. The application of HIIE in adolescents is contentious, however, with sceptics highlighting that the psychologically aversive nature and greater exertional stress of high-intensity exercise may lead to poor implementation and adherence (3). This contention is based on the dual mode theory (DMT), which explains the relationship between affective responses and exercise intensity (4). DMT predicts that in the moderate domain (intensities below the ventilatory threshold [VT]), there is low-to-moderate influence of cognitive factors (e.g. self-efficacy), and affective responses remain pleasurable. In the heavy domain (intensities from VT to maximal lactate steady state), cognitive factors have a strong influence, with interoceptive cues associated with the physiological strain of exercise (e.g. increased HR and ventilation) having a minimal influence. Thus, affective responses are likely to vary between individuals with some individuals interpreting the intensity as pleasurable, while others as an unpleasant feeling in the heavy domain. In the severe domain (intensities between maximal lactate steady state to the level of maximal exercise capacity or termed as high intensity exercise), there is a predominance of interoceptive cues due to the increased contribution of anaerobic sources, whereas a physiological steady state can no longer be maintained and is associated with unpleasant feelings (4). Research shows that affective responses are modulated not only by exercise intensity, but also by perceived exertion (5). Elucidating this information during HIIE is therefore important as affective evaluation during exercise may influence future attitudes towards PA behaviour in adolescents (6).

Several studies in youth provide support for the DMT showing exercise performed above the VT during incremental and continuous type protocols has an affective response that is negative and unpleasant (7, 8). Nonetheless, these evaluations were made during continuous or incremental exercise, which may not translate to HIIE involving brief bursts of high-intensity exercise separated by periods of light-intensity recovery exercise. Evidence from adults reveals that HIIE elicited more pleasurable feelings compared to continuous high-intensity exercise but less pleasurable or similar than continuous moderate-intensity exercise (9, 10). These findings show that low intensity exercise performed during the HIIE recovery intervals may not hold negative feelings and high exertional stress (i.e. perceived exertion), when the high-intensity exercise is performed in brief bursts interspersed with periods of recovery. Whether HIIE is perceived as aversive by youth populations however, is currently unknown.

Previous studies have shown that adolescents report greater enjoyment following HIIE, than when they engage in continuous moderate-intensity exercise (11, 12). However, enjoyment in previous adolescent HIIE studies was measured post-exercise, using the physical activity enjoyment scale (PACES). As post-exercise feelings may reflect a 'rebound' from the previous feeling stimulated during high-intensity exercise (4), important dynamic changes during exercise (13) may have been missed. Since adolescents prefer to engage in interval type exercise rather than continuous constant exercise regardless of exercise intensity (14), this pattern of activity seems important in promoting adherence to exercise interventions. Furthermore, children and adolescents perform their habitual physical activity in an intermittent (i.e. interval) manner (15), and there is strong evidence showing time spent performing moderate and vigorous physical activity is related to health benefits in this population (16). Therefore, it is crucial to compare enjoyment and affective responses between interval type protocols with different exercise intensities (e.g., moderate intensity vs. high intensity), both during and after exercise, in order to gain insight in terms of the feasibility of interval exercise in adolescent populations.

The purpose of the present study is to examine the acute affective, enjoyment and perceived exertion responses to HIIE and MIIE in adolescent boys. We also examined any potential relationship between enjoyment, perceived exertion and physiological responses with the affect responses during HIIE and MIIE. We hypothesised that 1) affective responses will decrease more during HIIE than MIIE and would be less positive during HIIE, 2) enjoyment would be similar during both HIIE and MIIE but greater enjoyment would be apparent after HIIE, and 3) there will be a significant correlation for enjoyment, perceived exertion and heart rate responses with the affective responses during HIIE but not in MIIE.

METHODS

Participants

Fourteen 13 to 15 years old adolescent boys were recruited into the study using a convenience sampling approach, with results presented for thirteen boys, as one boy dropped out for personal reasons unrelated to this study. The size of the sample was based on the ability to detect a medium to large effect in the affective responses (10) for a 2 (condition) by 8 (interval) repeated measures ANOVA with an alpha of 0.05 and power of 0.8. This resulted in an indicative sample size of 8 or 16 participants to detect a moderate and large effect respectively. The study procedures were granted by the Sport and Health Sciences Ethics Committee, University of Exeter. Written assent from the participants and written informed consent from the parent/guardian were obtained.

Anthropometric measures

Stature and body mass were quantified to the nearest 0.01 m and 0.1 kg using standard procedures. Body mass index (BMI) was calculated as body mass (kg) divided by stature (m) squared. Age and sex specific BMI cut-points for overweight and obese status were determined from Cole, Bellizzi (17). Percentage body fat was estimated using triceps and subscapular skinfolds to the nearest 0.2 mm (Harpenden callipers, Holtain Ltd, Crymych, UK) according to sex and maturation specific equations (18).

Experimental protocol

This study required three experimental sessions in the laboratory, separated by a minimum three-day rest period, and incorporated a within-measures design. The first visit was to measure anthropometric variables, determine cardiorespiratory fitness and familiarise participants with the measurement scales. This was followed by two experimental visits involving a running HIIE or MIIE protocol, the order of which was counterbalanced to control for any order effect. All exercise tests were performed using a motorised treadmill (Woodway PPS 55 Sport slate-belt treadmill, Woodway GmbH, Weil am Rhein, Germany).

Cardiorespiratory fitness

Participants were familiarised with walking and running on the treadmill before completing an incremental speed-based protocol and supramaximal test to establish maximal oxygen uptake ($\dot{V}O_{2max}$) and the VT. Participants began a warm-up against a speed of 4.0 km·h^{-1} for 3 min, followed by running at the speed of 6.0 km·h^{-1} with 0.5 km·h^{-1} increments every 30 s until volitional exhaustion, before a 5 min cool down at 4.0 km·h^{-1}. Throughout the incremental test, the treadmill gradient was set at 1%. Immediately 5 min after the cool down, participants performed a supramaximal test to exhaustion at 100% of maximal aerobic speed (MAS) obtained from the incremental test with the treadmill gradient set at 5%. The supramaximal test was used to confirm measurement of $\dot{V}O_{2max}$.

HIIE and MIIE protocols

Participants completed: 1) HIIE consisting of a 3 min warm-up at 4.0 km·h^{-1} followed by 8 x 1 min work intervals at 90% MAS determined from the incremental test; and 2) MIIE: between 9 - 12 x 1 min work intervals at 90% VT, where the numbers of work intervals matched the distance performed during HIIE condition for each participant. HIIE and MIIE intervals were interspersed with 75 s active recovery at 4 km·h^{-1}. A 2 min cool down at 4.0 km·h^{-1} was provided after each condition.

Measures

Gas exchange and heart rate

Expired gas exchange and ventilation variables during the cardiorespiratory fitness test and exercise protocols (HIIE and MIIE) were measured using a calibrated metabolic cart (Cortex Metalyzer III B, Leipzig, Germany). HR responses were recorded continuously using a telemetry system (Polar Electro, Kempele, Finland). Both gas exchange and HR data were subsequently averaged over 10 s intervals. The VT was determined from the incremental test data using the ventilatory equivalents for carbon dioxide production (VCO_2) and $\dot{V}O_2$. $\dot{V}O_{2max}$ was determined as the highest 10 s average in $\dot{V}O_2$ elicited either during the incremental or supramaximal test. Maximal HR (HR_{max}) was taken as the highest HR achieved during the incremental or supramaximal tests. The collection of gas exchange data during the exercise conditions in our study is to demonstrate the extent to which participants complied with the prescribed intensities which is in line with other studies in adolescents (11, 12).

Affective responses

Affective valence (pleasure/displeasure) was measured using the feeling scale (FS) (19) in line with previous work in adolescents (7, 8). Participants rated their current feelings on an 11-point bipolar scale ranging from +5 to -5, with anchors at zero ("Neutral") and at all odd integers, ranging from "Very Good" (+5) to "Very Bad" (-5). Activation levels were measured using the felt arousal scale (FAS). The FAS (20) is a single-item measure of perceived activation, with participants asked to rate themselves on a 6-point scale ranging from 1 to 6, with anchors at 1 'low arousal' and 6 'high arousal'. Participants were given standardised instructions on how to use the scales and were asked to provide their FS and FAS responses at 5 min before the exercise protocol, 20 s before the end of the warm-up session, 20 s before the end of each work and recovery interval, immediately post-exercise and 20 min post-exercise. FS and FAS were also obtained at the end of every stage during the incremental test to exhaustion to familiarise our participants with the scales and to link the affective responses data during incremental test to prevailing research on affect and enjoyment in adolescents. All the scales were administered by the same researcher.

Affective responses were also assessed from the perspective of the circumplex model (21), using a combination of FS and FAS scales (8). The circumplex is divided into 4 quadrants, each characteristic of different affective states: 1) unactivated/pleasant affect (e.g. calmness and relaxation); 2) unactivated/unpleasant affect (e.g. boredom or fatigue); 3) activated/unpleasant affect (e.g. tension or nervousness); and 4) activated/pleasant affect (e.g. excitement or happiness).

Perceived enjoyment

Participants rated their enjoyment during the exercise conditions on a 7-point exercise enjoyment scale (EES) (22). Participants were asked to rate their enjoyment in response to the standardised instruction: "Use the following scale to indicate how much you are enjoying this exercise session". Anchors were given at every integer, ranging from "Not at all" at 1 to

"Extremely" at 7. The EES was recorded 20 s at the end of the warm-up session, work and recovery intervals and the cool down. Enjoyment immediately after and 20 min after HIIE and MIIE was measured using the modified PACES, which is validated for use in adolescents (23). The PACES includes 16 items that are rated on a 5-point bipolar scale (score 1 = "strongly disagree" to score 5 = "strongly agree"). Total enjoyment was calculated by summing the 16 responses after seven items were reverse-scored. This procedure yielded a possible range of scores from 16 through to 80 with a higher score representing greater enjoyment.

Rating of perceived exertion

Rating of perceived exertion (RPE) was assessed using the 1–10 Pictorial Children's OMNI scale (24). The OMNI has a range of numbers familiar to youth (1 to 10) and uses age appropriate verbal expressions as descriptors of exercise effort. Anchors are given at every integer, ranging from 'not tired at all' (0) to 'very, very tired' (10). The same verbal instructions for using the scale were given to all participants before undertaking the exercise protocols. RPE was assessed at 20 s before the end of the warm-up session, end of the each work and recovery intervals, and end of the cool down.

Statistical analyses

All statistical analyses were conducted using SPSS (SPSS 22.0; IBM Corporation, Armonk, NY, USA). The Shapiro-Wilks test was used to test normality of distribution for the dependent variables. Data were analysed using a two-way repeated measure analysis of variance (ANOVA) to examine differences in affect, enjoyment and RPE between HIIE and MIIE over time (e.g. the work and recovery intervals). Due to the differences in the interval numbers between the HIIE and MIIE conditions, the initial 7th work (and 6th recovery) intervals in both conditions were compared, but the end interval of work and recovery in MIIE were compared against the 8th work interval (and 7th recovery interval) in HIIE. A series of one-way repeated measure ANOVA were conducted to examine differences in affect, enjoyment and RPE responses within either HIIE or MIIE. In the event of significant effects, follow-up pairwise comparisons were conducted to examine the location of mean differences. The magnitude of mean differences was interpreted using effect size (ES) calculated using Cohen's *d* (25), where an ES of 0.20 was considered to be a small change between means, and 0.50 and 0.80 interpreted as a moderate and large change, respectively. Pearson's product-moment correlation coefficient was used to examine the relationships of enjoyment, RPE and HR responses with affect responses during the work and recovery intervals.

Results

The participants' descriptive characteristics are presented in Table 1. Based on the age and sex specific aerobic fitness threshold cut-offs for poor cardiometabolic health (26), two participants were deemed to have a low level of fitness. One participant was categorised as overweight according to the international cut-offs for BMI (17).

Cardiorespiratory responses

The cardiorespiratory responses data from the exercise conditions are presented in Table 2. All participants successfully completed the HIIE and MIIE conditions. HIIE elicited higher absolute HR, percentage of maximal HR (%HR_{max}), absolute $\dot{V}O_2$ and percentage of maximal $\dot{V}O_2$ (%$\dot{V}O_{2max}$) for all work intervals than MIIE (all $P<0.01$).

Affective responses

Incremental test: FS showed a significant effect of time ($P<0.01$) during the ramp-incremental test to exhaustion. The FS significantly declined from min 1 to the VT (3.77 ± 1.24 vs. 1.77 ±

1.30; *P*<0.01, ES= 1.57), from the VT to VT + 1 min (1.77 ± 1.30 vs. 0.38 ± 1.81; *P*<0.01, ES= 0.88) and then from VT + 1 min to the end of the incremental test (0.38 ± 1.81 vs. -1.62 ± 1.98; *P*=0.02, ES= 1.05). Based on the FS and running speed relationship during the incremental test, the FS score was predicted to be circa -0.2 and +2.7 during HIIE and MIIE protocols respectively.

HIIE and MIIE conditions: FS responses during the HIIE and MIIE conditions are illustrated in Figure 1A. FS showed a significant condition by interval number interaction effect (*P*< 0.01). FS was significantly lower during HIIE than MIIE at work interval 5 to the end work interval (*P*<0.025, ES= 0.64 to 0.81) and at recovery interval 5 to the end recovery interval (*P*<0.012, ES=0.70 to 0.86). FS declined during the work intervals in both HIIE (*P*< 0.01) and MIIE conditions (*P*=0.028). Specifically, FS significantly decreased from the pre 5-min level at work interval 1 to work interval 8 during HIIE (*P*<0.01; ES= 0.49 to 1.49). In contrast, during MIIE the decrease from pre 5-min was significant at work-interval 2 to end work-interval (*P*<0.014; ES= 0.34 to 0.75). FS remained positive at the end work-interval in the MIIE condition (2.62 ± 1.50, where +2 represents the indicator between 'good' and 'fairly good') and the HIIE condition (1.15 ± 2.08, where +1 represents the 'fairly good' indicator). There were no significant differences (all *P*>0.51) for FS between HIIE and MIIE at pre 5-min, immediately and 20 min after exercise. Additionally, a total of 11 participants (85%) remained in a positive feelings (> 1 on FS) and two participants (15%) evoked a negative feeling at the end work interval in HIIE (< -1 on FS). In contrast all participants (100%) remained in positive affective responses in MIIE (> 2 on FS).

Correlations between FS and HR during the HIIE and MIIE conditions are illustrated in Figure 2A. A strong negative relationship was observed between absolute HR and %HRmax (r= -0.81, all P= 0.02) and with FS during the work intervals of HIIE. However, no significant correlations were observed between HR responses and the FS during HIIE recovery intervals (r = -0.56, all P= 0.06), and for the MIIE work and recovery intervals (all $r<-0.64$, $P>0.06$).

FAS responses during HIIE and MIIE are illustrated in Figure 1B. FAS showed a significant condition by interval number interaction ($P<0.01$). FAS was significantly greater during HIIE than MIIE at work interval 1 to end work interval ($P<0.01$; ES = 0.53 to 2.61) and at recovery interval 3 to end recovery interval ($P<0.02$; ES = 0.53 to 1.00). FAS increased during the work intervals in both exercise conditions (all $P<0.01$). Specifically, the increase from the pre 5-min level was significant at work interval 1 to end work-interval for HIIE ($P<0.01$; ES= 2.03 to 5.44) and MIIE ($P<0.01$; ES= 0.78 to 1.37). There were no significant differences (all $P>0.07$) between exercise conditions for FAS at pre 5-min, immediately and 20 min after exercise.

Affective responses (valence and activation) during the work and recovery intervals for HIIE and MIE were plotted onto a circumplex model (see Figures 3A and 3B). There was a shift from the unactivated/pleasant to the activated/pleasant quadrant for the HIIE work intervals, but affective responses remained in the unactivated/pleasant quadrant for the HIIE recovery intervals. In contrast, during MIIE, the affective responses remained in the unactivated/pleasant quadrant for the work and recovery intervals.

Exercise enjoyment responses

The enjoyment responses during HIIE and MIIE are illustrated in Figure 1C. EES only showed a significant main effect for interval number (P=0.001). EES declined during the work intervals for both HIIE (P=0.001) and MIIE (P=0.04). In both conditions, the decline from warm-up was significant from work-interval 5 to the end work-interval (all $P<0.006$: HIIE; ES=0.39 to 0.45;

MIIE, ES=0.33 to 0.58). There was a strong positive correlation between ESS and the FS responses for HIIE (*r*= 0.97, $P<0.01$) and MIIE (*r*= 0.86, *P*= 0.03,) as illustrated in Figure 2B.

PACES showed a significant condition by time interaction (*P*=0.007). PACES was significantly higher immediately and post 20-min of HIIE than MIIE (68 ± 6 vs. 64 ± 7, *P*=0.01, ES=0.47; 69 ± 5 vs. 61 ± 9, *P*=0.01, ES=1.10, respectively). PACES declined 20 min after MIIE (*P*=0.03, ES=0.34) but remained stable 20 min after HIIE (*P*=0.23, ES=0.19). A higher score immediately and post-20 min after HIIE compared to MIIE was found for PACES items "It's very exciting" (all $P<0.02$, ES$>$0.68) and "It gives me a strong feeling of success" ($p<0.04$, ES$>$1.10). In contrast, there was a higher and post-20 min after MIIE compared to HIIE for the item "I feel bored" ($p<0.08$, ES$>$0.91). There were no significant correlations between PACES and the FS responses during HIIE (all $r< 0.52$, all $P> 0.068$) and MIIE (all $r< 0.62$, all $P> 0.073$).

RPE responses

The RPE responses during HIIE and MIIE are illustrated in Figure 1D. RPE showed a significant condition by interval number interaction ($P<0.01$). RPE was significantly higher during HIIE than MIIE for all work intervals (all $P<0.03$, ES=0.64 to 2.27). RPE increased during the work interval in both conditions ($P<0.01$). During HIIE, the increase in RPE from warm-up was significant at work-interval 1 to work interval 8 ($P<0.01$, ES=1.61 to 5.44), whereas during MIIE, the increase was significant at work interval 1 to work interval 5 ($P< 0.01$, ES= 1.10 to 2.07), whereafter RPE remained stable to the end work interval (all $P>0.34$, ES= 2.40 to 2.47). There was a strong negative correlation between RPE and FS responses during HIIE (r= -0.97, $P<0.01$) but no significant correlation was present during MIIE (r= -0.66, *P*=0.06) as illustrated in Figure 2C.

DISCUSSION

The current study presents novel data on the affective, enjoyment and perceived exertion responses during HIIE and MIIE in adolescent boys. The key findings from this study are: 1) HIIE elicited a greater decline in affective valence than MIIE, but remained positive at the end work interval. A total of 85% of the participants remained in a positive feeling and 15% of the participants evoked a negative feeling at the end work interval in HIIE. In contrast 100% of the participants remained in positive affective responses in MIIE; 2) no significant differences between HIIE and MIIE were found for enjoyment responses during exercise, but HIIE elicited greater enjoyment immediately after and 20 min post exercise compared to MIIE. Furthermore, enjoyment responses declined 20 min after MIIE but not for HIIE; 3) affect and HR responses were significantly negatively correlated during HIIE work intervals, but not during HIIE recovery intervals and MIIE work and recovery intervals; 4) affect and enjoyment responses during exercise were positively correlated during both HIIE and MIIE; and 5) affect and RPE responses were negatively correlated during HIIE work intervals, but not during MIIE work intervals.

Previous affective responses studies in adolescents revealed that exercise at an intensity above the VT brings about a significant decline in affective valence, with scores below zero (e.g., -1.7 ± 2.8 of FS score) observed at the end of incremental exercise to exhaustion (7, 8). Our FS responses during and at the end of the ramp incremental test to exhaustion demonstrate similar findings (i.e., -1.6 ± 1.9 of FS score) and are consistent with previous work in adolescents and the DMT. In our study, we used the speed during HIIE and MIIE to predict the potential affect responses during these conditions according to the FS score elicited during the incremental test. Based on this, the FS score was predicted to be ~ -0.2 during HIIE and ~ +2.7 during MIIE.

We found that the overall mean scores for FS during MIIE work interval (i.e., 3.1 ± 0.23) was similar to prediction score, but were higher during the HIIE work intervals (i.e., 2.1 ± 0.76). Our findings are consistent with previous adult studies that show positive affect responses during HIIE, but slightly lower affect responses than continuous moderate-intensity exercise in sedentary and overweight adults (9, 10). We also found that affect responses were greater during recovery intervals compared to work intervals in both conditions (overall mean recovery: HIIE, 2.6 ± 0.47; MIIE, 3.3 ± 0.05). Therefore, our data indicate that the recovery intervals during HIIE have an influence on preserving the decline in FS. This is in line with the DMT, which predicts that a pleasurable feeling can occur during rest periods after an unpleasant stimulus or stress generated during work stimulus (4).

The DMT postulates that during high-intensity exercise, physiological factors (e.g. HR) have a strong influence on the affective responses. These factors show that the changes in affective responses during HIIE work and the recovery intervals are likely to be mediated by the physiological responses produced during these periods. Interestingly, we found a significant negative correlation between affect and HR responses during HIIE work intervals but not during HIIE recovery intervals and MIIE work and recovery intervals. According to the DMT (4), affective responses to exercise are regulated in a brain area, namely the prefrontal cortex (PFC) and the subcortical part. During high-intensity exercise, the functional capacity of the PFC becomes challenged by the intensified interoceptive cues (i.e. increased HR). This may induce deregulation in the PFC, resulting in a decreased (i.e. less positive/more negative) affective response mainly driven by the subcortical part (i.e. the amygdala). Although such mechanistic pathways are not exmained in the present study, it may be speculated that deregulation in the PFC might occur during HIIE work intervals, due to intensified HR responses (peak HR corresponding to 88% HR_{max}), compared to lower HR responses during

MIIE work intervals (peak HR corresponding to 72% HRmax). This deregulation may also explain the greater reductions in affective valence during HIIE, compared to MIIE (see Figure 1A), which is also consistent with previous research comparing HIIE to continous MIE in adults (9, 27). It has been reported that adolescents, in particular, reflect negative physiological cues, such as pains and aches, with a decline in their affect experience during high-intensity exercise (7). We speculate that the physiological variables associated with metabolic strain (i.e. HR, ventilation rate) exhibit a continuous upward "drift", which is in line with reported increases in HR during HIIE work intervals (28), marking an increase in the body's physiological and perceptual stress (see Figure 2C), potentially leading to pain and a burning sensation during HIIE, compared to MIIE.

We observed no significant differences between HIIE and MIIE for the FS score during the initial five work intervals, which may indicate that the recovery intervals preserved the unpleasant feelings of HIIE for about half of the total exercise bout. This finding is consistent with an adult-based study, which showed a similar affective response during the initial three work intervals of HIIE (29). We also found an increase in activation (measured by FAS) responses from work interval one to the end interval, accompanied by a decrease in affective valence in both conditions, which is in line with previous studies in youth involving incremental exercise to exhaustion (8, 30). We plotted valence and activation responses to a circumplex model (21) to differentiate the dynamic changes occuring during HIIE and MIIE. During HIIE, affective responses moved from the unactivated pleasant quadrant (i.e. evokes a sense of calmness and relaxation) and ended in the pleasant-activated quadrant (i.e. evokes a sense of excitement, enthusiasm, and happiness). However, affective responses remained in the unactivated pleasant quadrant during MIIE (see Figure 3). Our finding shows that the lack of activation (e.g. less excitement) may be a function of the overall exercise intensity of the MIIE trial being relatively easy and not too challenging. According to Rose and Parfitt (31), a positive affective response can be achieved if an individual perceives they have the ability to complete an exercise session when they are comfortably challenged, which may drive feelings of excitement and enjoyment (32). It therefore appears that our participants perceived HIIE protocol to be more challenging and at the same time have ability to cope with the prescribe exercise intensity and complete the HIIE protocol, which in turn led to increased feelings of excitement compared to MIIE.

We observed a small to medium reduction in enjoyment responses measured by EES during both HIIE (ES=0.39 to 0.45) and MIIE (ES=0.33 to 0.58) after the 5^{th} work interval, indicating that enjoyment responses were maintained over initial ~ 50% of the total work for both conditions. The same finding was previously observed by Martinez, Kilpatrick (10), who reported a small decline in EES near the end of the work interval of HIIE with shorter intervals (i.e. 30 s and 60 s) in overweight adults. These authors also suggest that the pattern of enjoyment responses is similar to affective responses during HIIE work interval. Interestingly, we found a strong positive correlation between enjoyment and affective responses during exercise in both conditions. Raedeke (33) suggest that enjoyment responses were positively related to positive affect but unrelated to negative affect. Our data seems to support this observation, as both conditions elicited positive affective responses to the interval exercise. The present study is the first to evidence the enjoyment responses during exercise conditions, by using a single-item scale of EES in adolescents. However, EES has only been used in a few studies in adults (10, 22), and there is a possibility of erroneous responses (due to confusion or carelessness), due to the single-item measure, as compared to the multi-item measure of the same construct (e.g. PACES). Therefore, the enjoyment responses during exercise conditions that are presented in this study may be speculative.

In contrast to the enjoyment during exercise, we observed greater enjoyment, as measured by PACES, after HIIE compared to MIIE. This is consistent with previous HIIE studies on adolescents that contrasted against work-matched continuous moderate-intensity exercise (12). Interestingly we found no significant correlations between affect responses and post-enjoyment in both exercise conditions, which is contrary with enjoyment responses during exercise. This difference may be due to the measurement tools used to identify enjoyment responses during (single item of EES) and after (PACES questionnaire) exercise. However, our finding of no significant relationship between affect and post-exercise enjoyment could be explained via distinctions between affect and enjoyment (34). Specifically, affect only represents general feelings that are independent of the cognitive process, whereas enjoyment (emotional experience) is elicited following a cognitive appraisal process during which a stimulus (i.e. exercise intensity) is recognised as either beneficial or detrimental to the person. In this present study, we found that HIIE elicited a strong feeling of success and a feeling of excitement immediately and after 20 minutes of exercise based on the individual PACES items which in line with our previous study that examined individual items on PACES scale following HIIE in adolescent boys and girls (28). In contrast, participants rated a higher score in the item 'I feel bored' immediately and after 20 minutes of MIIE. This may explain the decline in PACES score following 20-min of MIIE but not in HIIE. Research findings show that an increase in enjoyment could lead to an increase in PA as feeling of enjoyment serves an immediate reward for being physically active (35). Therefore, our findings provide foundations to highlight that enjoyment and affective responses during HIIE protocol could possibly improve PA levels in contrast to MIIE while the retention to PA is a recurrent challenge.

We found an increase in RPE during the HIIE work intervals but an opposite pattern was observed for the affective responses, which are consistent with previous HIIE studies in adults (5, 29). Our study also revealed a strong negative correlation between RPE and the affective response to HIIE but not during MIIE. This is consistent with the study by Acevedo, Rinehardt (36) who revealed that RPE and affect responses were correlated during continuous high-intensity exercise but not during continuous moderate-intensity exercise in well trained adults. This finding can be explained through the parallel processing model proposed by Leventhal and Everhart (37). The parallel processing model proposes that an increase in an individual's exertional responses (i.e. fatigue and pain) is reflected by an increase in physiological cues (e.g. HR). Thus, during HIIE, when physiological cues become predominant during exercise, exertional responses will occupy the limited capacity of focal awareness (the sensory data to which one chooses to attend) to the brain area (i.e. PFC) which might not occur during MIIE. Also our data strengthens the idea proposed by Oliveira, Viana (5) which suggests affective responses are not only mediators of the exercise intensity, but also 'how' the individuals perceive the intensity that they are performing.

There are several limitations that should be acknowledged. This study is limited to the recruitment of healthy adolescent boys with a small sample size. Therefore, data cannot be generalised to more diverse groups (e.g., adolescent girls, different fitness level). Despite this limitation, the exercise protocols adopted in this study have already been shown to be feasible and enjoyable for both adolescent boys and girls (11, 12). Moreover, no sex differences were identified in previous studies examining affective responses in adolescents (7, 8). Future research examining affect and enjoyment responses, however, need to include both sexes to investigate whether there are any potential sex differences. This study utilised a facemask during the exercise conditions for the collection of gas exchange data, which will not be representative of the ‘real world’ setting and may influence the exercise perceptual responses. However, our previous work has shown that a similar external work-rate (i.e. power output) for HIIE does not adequately describe the internal work demand (e.g. HR and $\dot{V}O_2$) during the exercise (28). Given this observation, it is important to collect the gas exchange and HR data during the experimental trials. Furthermore to limit the effect of the facemask, its use was standardised across all the experimental trials to avoid any method biases (e.g. any possible effects of wearing [or not] the facemask on the perceptual responses to exercise). This methodological approach was also in line with a previous study examining affective responses to incremental exercise in youth (8). Another limitation is that this study did not measure the PA level of the participants. Moreover, our participants had a high cardiorespiratory fitness level (~ 50 $mL \cdot min^{-1} \cdot kg^{-1}$). Given that previous research has highlighted that affective responses during exercise are influenced by the previous activity history of participants (7, 30), future research may benefit from an attempt to recruit participants with a range of fitness levels to evaluate any differences in affect and enjoyment responses during HIIE. Also, research should examine the role of affect and enjoyment during HIIE with a different protocol as multiple numbers of HIIE protocols can be prescribed by altering the intensity and duration of the work and recovery intervals, which in turn may alter the intensity-affect relationship.

PRACTICAL IMPLICATIONS

This study explores adolescent boys' affective, enjoyment and exertional responses during HIIE and MIIE protocols. Given that the HIIE protocol used in our study has been shown to produce health benefits in previous adolescents based studies (11, 12), this type of HIIE protocol could be an effective health improvement strategy, which appeals to adolescents due to the positive affect and greater post-enjoyment responses compared to MIIE. The HR responses (e.g. peak HR and average HR during work interval) collected in our study could be used to further aid intensity prescription for non-laboratory based HIIE protocols (38), such as those conducted in schools (39), where the need for inexpensive and practical exercise intensity monitoring tools is essential. We also recommend the practical use of simple tools of psychometric measurement (i.e. FS, RPE, and EES scale) to prescribe and monitor HIIE. Thus, combining HR and psychometric tools may offer useful strategies to monitor HIIE by teachers or exercise professionals.

CONCLUSION

Our data show that HIIE can negate the prominent negative affective responses predicted by DMT, as has been shown in incremental tests and continuous high-exercise protocols in adolescents (7, 8). Despite HIIE resulting in a greater decline and lower affective responses compared to MIIE, which fit the expected pattern of responses by DMT, the low intensity exercise performed during recovery may not hold prominent negative emotions during HIIE. Therefore, the DMT may require modification, in order to more adequately consider the influence of interval exercise on affective responses to exercise. Our study also shows that HR, RPE and enjoyment responses are significantly correlated to the affect responses changes during HIIE. Despite greater cardiorespiratory and perceived exertion responses during HIIE than MIIE, participants reported HIIE to be pleasant and more enjoyable than MIIE. Therefore, our findings show that HIIE does not elicit a psychologically aversive nature as proposed by others (3, 40) and demonstrates the feasibility of the application of HIIE as an alternative form of exercise in adolescents.

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DISCLOSURES

The authors have no conflicts of interest to disclose.

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Figures caption

Figure 1. Feeling scale (A), felt arousal scale (B), exercise enjoyment scale (C) and rating of perceived exertion (D) during the interval and recovery phases of the HIIE (●) and MIIE (○). Where, W= work interval, R= recovery interval, endW= work interval 8 in HIIE and end work interval for MIIE, and endR= recovery interval 7 in HIIE and end recovery interval for MIIE. *Significant difference between HIIE and MIIE. #Significant condition by interval number. Error bars are presented as SD. See text for details.

Figure 2. Correlation analysis between Feeling scale (FS) and heart rate (A), exercise enjoyment scale (B) and rating of perceived exertion (C) during HIIE (●) and MIIE (○) work intervals. Abbreviations: Ventilatory threshold (VT), which is denoted by the vertical dotted

line. *Significantly negative correlations. #Significantly positive correlations. See text for details.

Figure 3. Valence (FS) and activation (FAS) during the work and recovery interval of HIIE (A) and MIIE (B) plotted onto the circumplex model. HIIE work interval (●) and recovery interval (■); MIIE work interval (○) and recovery interval (□). Where, W= work interval, R= recovery interval and endW= work interval 8 in HIIE and end work interval for MIIE. See text for details.

Table 1 Descriptive characteristics of the participants (n = 13)

	Mean ± SD	Min	Max
Age (y)	14.0 ± 0.5	13.1	15.0
Body mass (kg)	49.6 ± 13.7	34.8	80.3
Stature (m)	1.62 ± 0.11	1.47	1.85
BMI (kg·m^{-2})	18.6 ± 3.2	14.5	26.7
Body fat (%)	12.7 ± 6.4	7.6	31.8
HR_{max} (bpm)	197 ± 10	175	213
MAS (km·h^{-1})	15.3 ± 2.1	10.5	17.5
$\dot{V}O_2$ (L·min^{-1})	2.48 ± 0.52	1.79	3.63
$\dot{V}O_{2max}$ (mL·min^{-1}·kg^{-1})	50.9 ± 5.5	36.0	56.0

HR at VT (bpm)	163 ± 10	141	172
RPE at VT	3.9 ± 0.8	3	6
VT ($L \cdot min^{-1}$)	1.72 ± 0.33	1.25	2.44
VT (%$VO_{2\ max}$)	69.9 ± 3.8	64.4	78.3

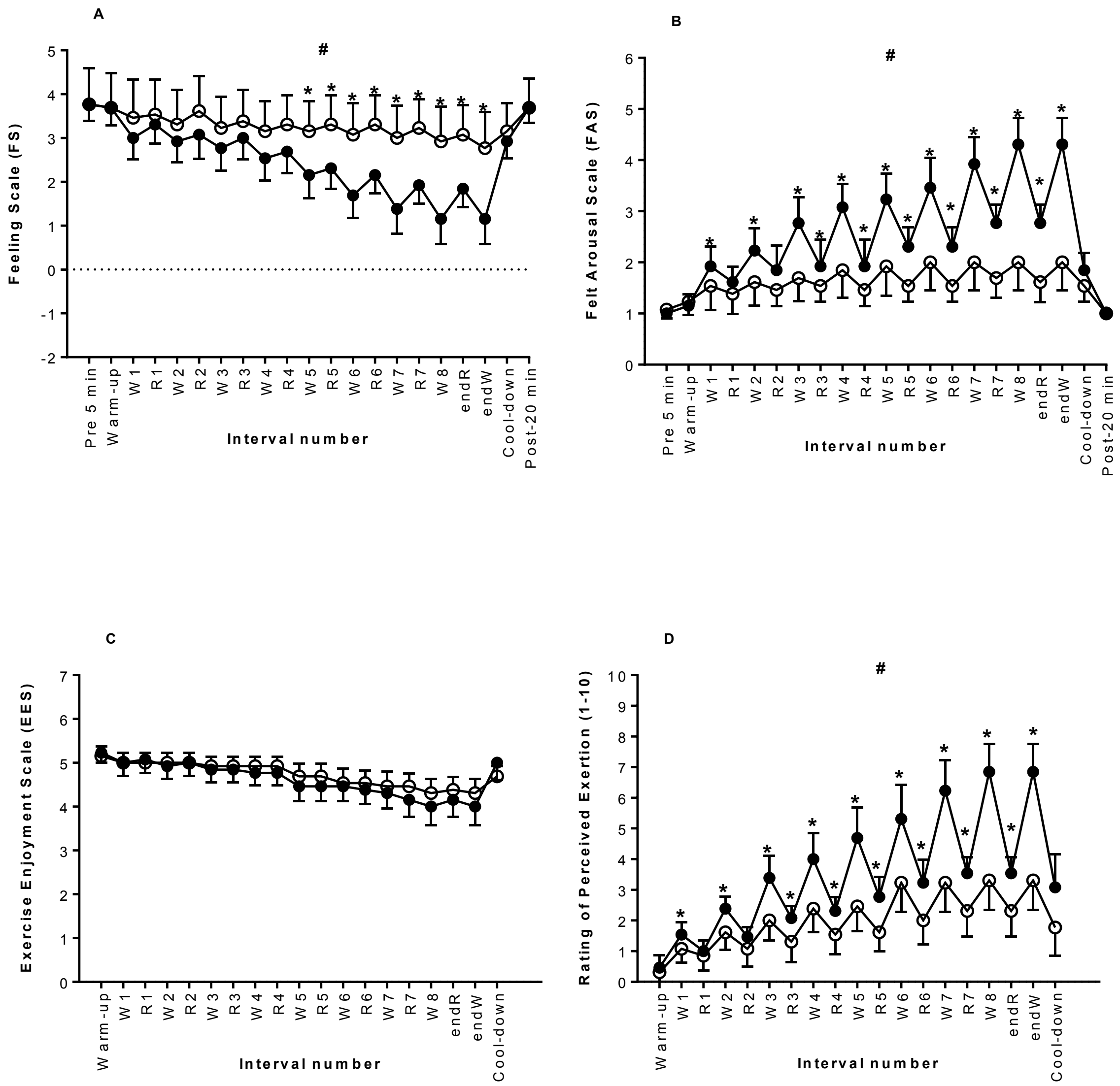
Values are reported as mean ± standard deviation. Abbreviations: BMI, body mass index; $\dot{V}O_{2max}$, maximal oxygen uptake; HR_{max}, maximal heart rate; %$\dot{V}O_{2max}$, percentage of maximal oxygen uptake; VT, ventilatory threshold; MAS, maximal aerobic speed.

Table 2 Cardiorespiratory responses to HIIE and MIIE

	HIIE	MIIE	*P*-value	ES
Speed ($km \cdot h^{-1}$)	13.8 ± 1.9	8.8 ± 0.9	**<0.01**	3.36
Average HR (bpm)	155 ± 26	125 ± 20	**<0.01**	1.29
Average % HRmax	77 ± 13	63 ± 10	**<0.01**	1.21
Peak HR (bpm)	177 ± 13	143 ± 17	**<0.01**	2.25
Peak %HRmax	88 ± 4	72 ± 7	**<0.01**	2.81

Average $\dot{V}O_2$ (L·min^{-1})	1.55 ± 0.48	1.12 ± 0.34	**<0.01**	1.03
Average $\dot{V}O_2$ (%$\dot{V}O_{2max}$)	62 ± 19	44 ± 14	**<0.01**	1.08
Peak $\dot{V}O_2$ (L·min^{-1})	2.01 ± 0.45	1.46 ± 0.36	**<0.01**	1.35
Peak $\dot{V}O_2$ (%$\dot{V}O_{2max}$)	82 ± 8	58 ± 5	**<0.01**	3.60

Values are reported as mean ± standard deviation, probability (*P*), and effect size (ES). Significant differences are shown in bold. Abbreviations: HR, heart rate; HR_{max}, maximal heart rate; $\dot{V}O_2$, oxygen uptake: $\dot{V}O_{2max}$, maximal oxygen uptake; %$\dot{V}O_{2max}$, percentage of maximal oxygen uptake; VT, ventilatory gas exchange.



A
#
Feeling Scale (FS)
5
4
3
2
1
0
-1
-2
Pre 5 min
Warm-up
W 1
R 1
W 2
R 2
W 3
R 3
W 4
R 4
W 5
R 5
W 6
R 6
W 7
R 7
W 8
endR
endW
Cool-down
Post-20 min
Interval number
B
#
Felt Arousal Scale (FAS)
6
5
4
3
2
1
0
Pre 5 min
Warm-up
W 1
R 1
W 2
R 2
W 3
R 3
W 4
R 4
W 5
R 5
W 6
R 6
W 7
R 7
W 8
endR
endW
Cool-down
Post-20 min
Interval number
C
Exercise Enjoyment Scale (EES)
7
6
5
4
3
2
1
0
Warm-up
W 1
R 1
W 2
R 2
W 3
R 3
W 4
R 4
W 5
R 5
W 6
R 6
W 7
R 7
W 8
endR
endW
Cool-down
Interval number
D
#
Rating of Perceived Exertion (1-10)
10
9
8
7
6
5
4
3
2
1
0
Warm-up
W 1
R 1
W 2
R 2
W 3
R 3
W 4
R 4
W 5
R 5
W 6
R 6
W 7
R 7
W 8
endR
endW
Cool-down
Interval number

Figure 1

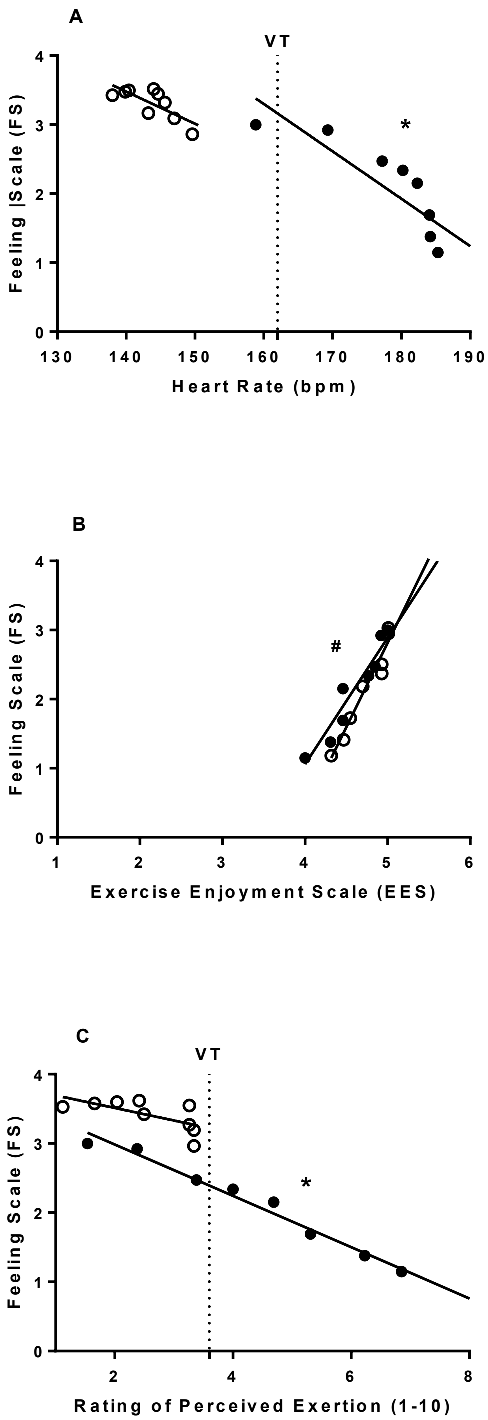

A
VT
Feeling |Scale (FS)
Heart Rate (bpm)
130 140 150 160 170 180 190
0 1 2 3 4
*
B
Feeling Scale (FS)
Exercise Enjoyment Scale (EES)
1 2 3 4 5 6
0 1 2 3 4
#
C
VT
Feeling Scale (FS)
Rating of Perceived Exertion (1-10)
2 4 6 8
0 1 2 3 4
*

Figure 2

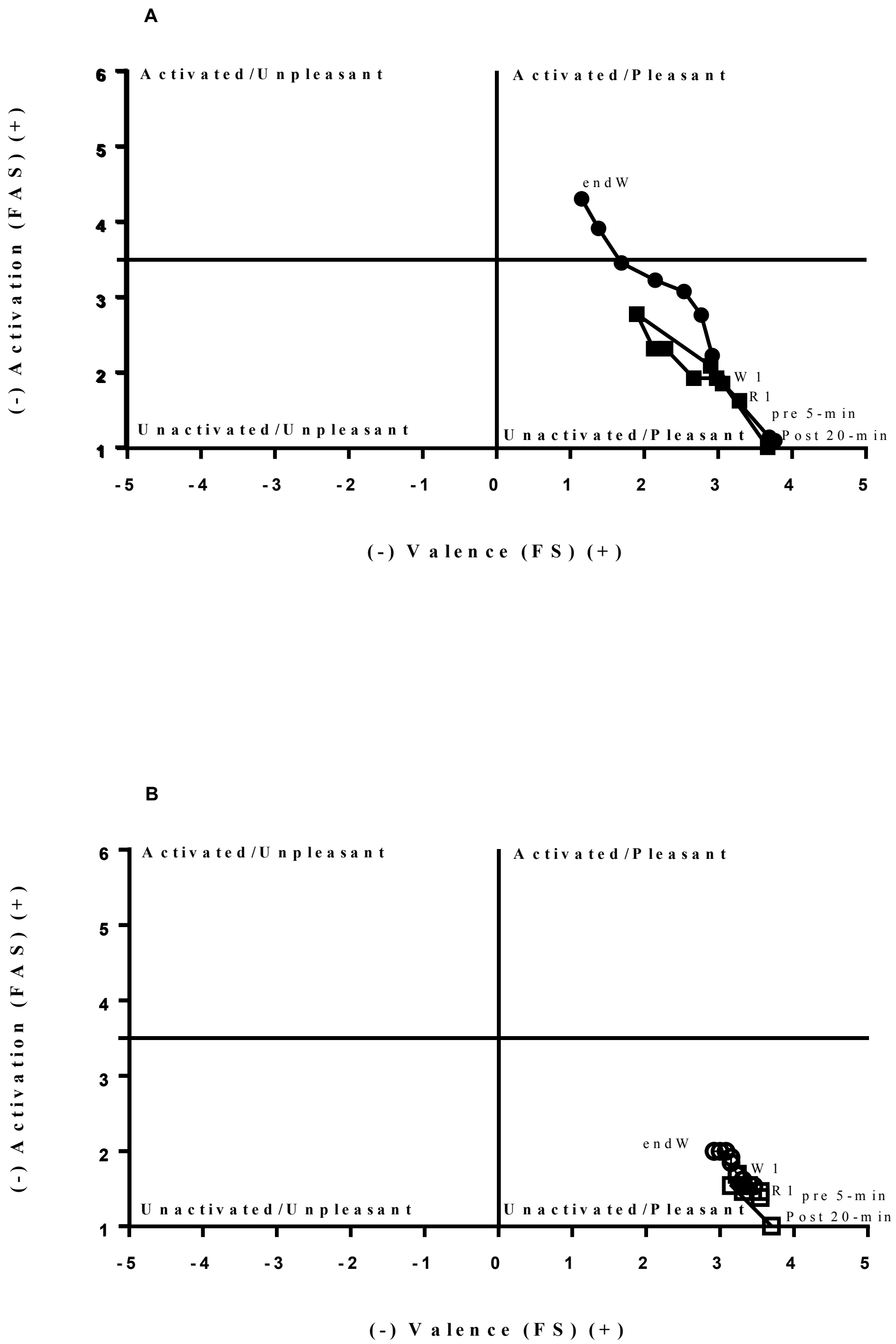

A
Activated/Unpleasant
Activated/Pleasant
Unactivated/Unpleasant
Unactivated/Pleasant
endW
W1
R1
pre 5-min
Post 20-min
(-) Activation (FAS) (+)
(-) Valence (FS) (+)
B
Activated/Unpleasant
Activated/Pleasant
Unactivated/Unpleasant
Unactivated/Pleasant
endW
W1
R1
pre 5-min
Post 20-min
(-) Activation (FAS) (+)
(-) Valence (FS) (+)

Figure 3