EXAMINING THE PSYCHOLOGICAL AND BEHAVIOURAL IMPLICATIONS OF INTERVAL EXERCISE FOR PHYSICALLY INACTIVE ADULTS

by

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The following individuals certify that they have read, and recommend to the College of Graduate Studies for acceptance, a thesis/dissertation entitled:

**EXAMINING THE PSYCHOLOGICAL AND BEHAVIOURAL IMPLICATIONS OF INTERVAL EXERCISE FOR PHYSICALLY INACTIVE ADULTS**

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Abstract

Interval exercise refers to short, intermittent bouts of high-intensity exercise separated by periods of recovery. A surge of interest in interval exercise over the past decade has advanced our understanding of the physiological and health benefits of interval exercise training among healthy individuals and those with cardiometabolic diseases. This has led to growing interest from the perspective of improving public and population health, given that interval exercise training can be a time-efficient exercise strategy to elicit adaptations typically associated with long-duration traditional continuous exercise training. However, the psychological outcomes and behavioural implications of engaging in interval exercise for largely inactive populations are less clear and have become the topic of intense debate. Thus, this thesis aimed to shed light on the ongoing debate by comprehensively evaluating the existing research evidence and examining the psychological and behavioural implications of engaging in interval exercise among physically inactive adults. First, a scoping review was conducted to provide a comprehensive synthesis of the existent research evidence on the psychological responses to interval exercise. Second, a mixed-methods experimental approach was used to study thirty inactive participants’ psychological responses to acute bouts of interval and continuous exercise performed in a lab setting and their subsequent real-world exercise behaviour. Third, a repeated-measures crossover design was used to study the effects of motivational music on the psychological, psychophysical and physiological responses to a practical interval exercise protocol among twenty-four insufficiently active adults. The primary findings of this thesis were: 1) emerging research evidence supports the viability of interval exercise as an alternative to continuous exercise; 2) single sessions of interval exercise can be as enjoyable and preferable as traditional continuous exercise among
inactive individuals; 3) there may be differences in the affect-behaviour relationship between interval and continuous exercise; and 4) the application of motivational music during interval exercise may be a viable strategy to enhance affect, enjoyment, and performance of interval exercise for insufficiently active adults. Overall, the contributions from this dissertation provide a critical advancement to our understanding about the viability of interval exercise and its potential to improve physical activity among largely inactive populations.
Lay Summary

Interval exercise refers to short bouts of high-intensity exercise separated by periods of rest. An increased understanding of the physical health benefits of interval exercise has led to growing interest from the perspective of improving public health, given that interval exercise is time-efficient compared to traditional long-duration continuous exercise. However, the viability of interval exercise for the general population is less clear and has become the topic of intense debate. This thesis aimed to evaluate inactive people’s psychological and behavioural responses to interval exercise. A review of the current research evidence and two controlled laboratory experiments were conducted. The findings showed that interval exercise can be as enjoyable and preferable as continuous exercise, and that music can be used to enhance people’s psychological responses to interval exercise. Overall, this dissertation provides a new understanding of interval exercise and its potential to improve physical activity among largely inactive populations.
Preface

I declare that the composition of this thesis in its entirety is my own. In the case of co-authored work, all sources have been acknowledged and contributions to each study are outlined below. All experimental chapters in this thesis were approved by the respective research ethics boards at McMaster University, the University of British Columbia (Okanagan), and Brunel University London.

Chapter 2 (Study 1)

With journal permission, this Chapter consists of a Post-Peer Review Version (unedited, prior to journal copy-editing and formatting) of an article published by Taylor & Francis in Health Psychology Review on June 1, 2017, available online:


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Systematic Searches & Data Analysis: McMaster University & University of British Columbia (Okanagan)

Manuscript/Chapter Writing: University of British Columbia (Okanagan)
M. J. Stork’s role in Study 1:

- Conceived scoping review searches and methods
- Conducted full systematic search and study selection process
- Completed full data extraction and charting
- Supervised volunteer who assisted with study selection and extraction process
- Primary and corresponding author of manuscript, drafted manuscript, provided revisions for publication

Role of co-authors in Study 1:

- KMG provided guidance for all stages of the project
- KMG and LEB assisted MJS with study conceptualization and methods
- LEB provided guidance to MJS for the systematic search, study selection, data extraction and charting stages
- MJG assisted MJS in assessing the descriptions of the exercise protocols and classifying them for the charting process
- KMG assisted MJS with interpretation and charting of the extracted data
- KMG, LEB and MJG revised and approved of the final version of the manuscript before submission to Health Psychology Review

Chapter 3 (Study 2 – Quantitative Component)

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Data Collection: McMaster University

Data Analysis and Manuscript/Chapter Writing: University of British Columbia (Okanagan)

M. J. Stork’s role in Study 2 – Quantitative Component:

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- Administered all lab protocols and measures and data collection
- Completed all data input, analysis and interpretation
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Role of co-authors in Study 2 – Quantitative Component:

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- KMG assisted MJS with obtaining ethics approval at McMaster University
- KMG and MJG assisted MJS with interpretation of the data
- KMG and MJG revised and approved of the final version of the manuscript before submission to *Medicine & Science in Sports & Exercise*

Ethics Approval: This study protocol was approved by the McMaster Research Ethics Board (MREB # 2012 204).

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• KMG assisted MJS with obtaining ethics approval at McMaster University
• TLW provided guidance for the entire thematic analysis process and acted as a critical friend in the coding and analysis process
• KMG and TLW assisted MJS with interpretation of the data
• KMG and TLW provided feedback on writing of the qualitative component of Chapter 3

Ethics Approval: This study protocol was approved by the McMaster Research Ethics Board (MREB # 2012 204).

Chapter 4 (Study 3)

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Data Collection: Brunel University London

Data Analysis and Chapter Writing: Brunel University London & University of British Columbia (Okanagan)

M. J. Stork’s role in Study 3:

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- Responsible for full participant recruitment
- Lead investigator responsible for preparation of lab settings, materials, and scripts
- Administered all lab protocols and measures and data collection
- Completed all data input, analysis and interpretation
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- KMG and CIK assisted MJS with study design, protocols and measurement selection
- KMG assisted MJS with obtaining ethics approval at the University of British Columbia
• CIK assisted MJS with obtaining ethics approval at Brunel University London
• KMG and CIK assisted MJS with interpretation of the data
• KMG provided feedback on the writing of Study 4 into Chapter 4

**Ethics Approval:** This study protocol was approved by the University of British Columbia Clinical Research Ethics Board (CREB # H17-00430) and Brunel University London’s College of Health and Life Sciences Research Ethics Committee (Reference # 6265-LR-Mar/2017-6695-1)
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Dedication

My PhD dissertation is dedicated to two of my biggest supporters in life and on my PhD journey. My grandfather and uncle,

Sam Sniderman (1934-2016) and David Sniderman (1962-2016)
### List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>ACSM</td>
<td>American College of Sports Medicine</td>
</tr>
<tr>
<td>ANOVA</td>
<td>Analysis of variance</td>
</tr>
<tr>
<td>ART</td>
<td>Affective-Reflective Theory</td>
</tr>
<tr>
<td>BMI</td>
<td>Body mass index</td>
</tr>
<tr>
<td>BMRI-3</td>
<td>Brunel Music Rating Inventory-3</td>
</tr>
<tr>
<td>BWIT</td>
<td>Body-weight interval training</td>
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<tr>
<td>FAS</td>
<td>Felt Arousal Scale</td>
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<tr>
<td>FS</td>
<td>Feeling Scale</td>
</tr>
<tr>
<td>HIIT</td>
<td>High-intensity interval training</td>
</tr>
<tr>
<td>HR</td>
<td>Heart rate</td>
</tr>
<tr>
<td>HRmax</td>
<td>Maximal heart rate</td>
</tr>
<tr>
<td>IPAQ-SF</td>
<td>International Physical Activity Readiness Questionnaire – Short Form</td>
</tr>
<tr>
<td>MICT</td>
<td>Moderate-intensity continuous training</td>
</tr>
<tr>
<td>PACES</td>
<td>Physical Activity Enjoyment Scale</td>
</tr>
<tr>
<td>PAR-Q</td>
<td>Physical Activity Readiness Questionnaire</td>
</tr>
<tr>
<td>RPE</td>
<td>Ratings of Perceived Exertion</td>
</tr>
<tr>
<td>SCT</td>
<td>Social Cognitive Theory</td>
</tr>
<tr>
<td>SIT</td>
<td>Sprint interval training</td>
</tr>
<tr>
<td>SPSS</td>
<td>Statistical Package for the Social Sciences</td>
</tr>
<tr>
<td>TPB</td>
<td>Theory of Planned Behaviour</td>
</tr>
<tr>
<td>VICT</td>
<td>Vigorous-intensity continuous training</td>
</tr>
<tr>
<td>VO$_2$max</td>
<td>Maximal oxygen uptake</td>
</tr>
<tr>
<td>VT</td>
<td>Ventilatory threshold</td>
</tr>
<tr>
<td>WAnT</td>
<td>Wingate Anaerobic Test</td>
</tr>
<tr>
<td>Wmax</td>
<td>Maximal power output in Watts</td>
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</table>
Chapter 1: Introduction

Despite the countless benefits of regular physical activity for health and well-being (e.g., Penedo & Dahn, 2005; Warburton, Nicol, & Bredin, 2006), physical inactivity remains a leading public health problem (e.g., Blair, 2009; Kohl III et al., 2012). Given the extensive global health, economic, social and environmental consequences of physical inactivity, it has even been described as a “pandemic” (Kohl III et al., 2012). Approximately 31% of the world’s adult population is failing to meet minimal physical activity guidelines (Hallal et al., 2012). What is even more troubling is that physical activity trends suggest a decrease in activity levels over time (Church et al., 2011; Knuth & Hallal, 2009; Kohl III et al., 2012). In other words, inactivity rates are not getting any better.

In wake of the physical inactivity pandemic, exercise scientists have continued to explore various exercise intervention strategies and alternatives that may have the potential to combat key barriers to physical activity and increase the likelihood of participation. In particular, a perceived lack of time has been one of the most frequently cited barriers to physical activity (e.g., Biddle, Mutrie, & Gorely, 2015; Stutts, 2002; Trost, Owen, Bauman, Sallis, & Brown, 2002), and has received a great deal of attention. As such, there has been a recent growth of interest in developing exercise options that may be able to combat this barrier to physical activity. Consequently, this has led to the emergence of interval exercise – a more time-efficient alternative to traditional, long-duration continuous exercise.

1.1 Interval Exercise

Interval exercise has been defined as exercise that involves repeated short, high-intensity efforts that are separated by periods of low-intensity rest or recovery and that typically last approximately 20-25 minutes or less (e.g., Batacan, Duncan, Dalbo, Tucker, &
Due to its intermittent nature, numerous variations of interval exercise protocols are possible. Protocols can vary in the total exercise duration, the number and intensity of work bouts completed, and the duration of work and rest periods (e.g., Cassidy, Thoma, Houghton, & Trenell, 2017; Weston, Wisløff, & Coombes, 2014). Thus, when assessing the interval exercise literature, it is important to carefully consider the differences between various interval exercise protocols and the terminology used to describe them (Stork, Banfield, Gibala, & Martin Ginis, 2017). Based on the recommendations of Weston et al. (2014) for defining interval exercise protocols, high-intensity interval training (HIIT) refers to relatively intense but submaximal efforts that generally elicit ≥80% of maximal heart rate (HRmax). Sprint interval training (SIT) refers to “all-out” or “supramaximal” efforts performed at a workload that elicits ≥100% of maximal oxygen uptake (VO₂max).

1.2 Interval Exercise for the Largely Inactive Population

While early research on the physiological adaptations to interval exercise dates back to the 1960s (I. Astrand, P. Astrand, Christensen, & Hedman, 1960), there has been a major surge of interest in interval exercise over the last 10 years. Firstly, researchers have taken aim at furthering our understanding of the various physiological health benefits of interval exercise. Specifically, a large body of exercise physiology research has consistently shown that interval exercise training can induce similar metabolic and cardiovascular health benefits to traditional moderate-intensity continuous exercise training (MICT), but with a much shorter time commitment (e.g., Batacan et al., 2017; Gibala, Gillen, & Percival, 2014).

Secondly, the widespread popularity of interval exercise among the general public is a phenomenon that is simply hard to ignore. In 2014, interval exercise took over as the
number one fitness trend based on the American College of Sports Medicine (ACSM)’s annual worldwide survey (Thompson, 2017). Since then, it has remained as a top three fitness trend and, most recently, topped the rankings again as number one in 2018 (Thompson, 2017). Put simply, people are intrigued by the concept of interval exercise and many are interested in trying it.

In light of the expanding interest in interval exercise from researchers and the general public alike, there has also been rising interest from the perspective of improving public and population health. While early interval exercise studies have focused on physically active and fit individuals undergoing intense interval exercise protocols (e.g., Burgomaster, Hughes, Heigenhauser, Bradwell, & Gibala, 2005; Weston et al., 1996), more recent research has shifted towards studying interval protocols that may be more practical and appropriate for less active or clinical populations (Astorino & Thum, 2016b; Vollaard & Metcalfe, 2017). Advances in interval exercise research have progressed our knowledge about the metabolic and cardiovascular health benefits of interval exercise training not only for healthy active individuals, but also for those who are less active and may be living with cardiometabolic diseases (Batacan et al., 2017; Gibala et al., 2014; Weston et al., 2014). While the accumulating research evidence on the physiological benefits of interval exercise have been promising, the psychological outcomes and behavioural implications of engaging in interval exercise for largely inactive populations are less clear and have become the topic of intense debate.

1.3 The Debate: Is Interval Exercise Appropriate for Largely Inactive Populations?

In recent years, there has been a great deal of discussion and debate about whether interval exercise should be promoted in public health strategies and messages encouraging
physical activity participation. Much of this debate has been generated from a number of published commentaries and opinion articles that are based on researchers’ conflicting perspectives on how people may respond psychologically to interval exercise and the subsequent influence this may have on exercise behaviour and adherence. For example, an opinion article published in 2014 entitled, “Why sprint interval training is inappropriate for a largely sedentary population” (Hardcastle, Ray, Beale, & Hagger, 2014) has since sparked numerous published responses and rebuttals (e.g., Astorino & Thum, 2016b; Del Vecchio, Gentil, Coswig, & Fukuda, 2016; Jung, Little, & Batterham, 2016; Robertson-Wilson, Eys, & Hazell, 2017). Based on a debate that was held at an international research conference, an article titled, “High-intensity interval exercise training for public health: A big HIT or shall we HIT it on the head?” was published in 2015 (Biddle & Batterham, 2015). The ongoing debate has been largely driven by contrasting perspectives and theoretical viewpoints about the viability of interval exercise for the general public.

1.3.1 The Debate: “The Critics”

Many of the critics of interval exercise argue that it is not a sustainable public health strategy because many people will not participate or adhere to it in the long-term (Biddle & Batterham, 2015; Hardcastle et al., 2014). This opinion is predominantly based on the notion that interval exercise will induce negative affective responses for most people, which will ultimately discourage exercise engagement (e.g., Biddle & Batterham, 2015; Hardcastle et al., 2014). One theory that has been used to support this position is the dual-mode theory (Ekkekakis, 2003).

The dual-mode theory (Ekkekakis, 2003) proposes that people’s affective responses to exercise will become progressively more negative during high-intensity exercise
performed above the ventilatory threshold (VT) – the point at which one’s ventilation rate exceeds the rate of oxygen uptake during exercise. It has been proposed that, “In this range, the amount and intensity of interoceptive information increases exponentially, as the accumulating lactate stimulates free nerve endings,” (Ekkekakis, 2003, p. 227) which subsequently stimulate affective centres of the brain (e.g., amygdala), and affective valence becomes more negative. Importantly, there is evidence that affective responses during continuous exercise are predictive of future exercise behaviour (e.g., Rhodes & Kates, 2015; Williams, Dunsiger, Jennings, & Marcus, 2012). Following this line of reasoning, it has been suggested that individuals will experience negative affect during interval exercise protocols, and this will subsequently discourage future interval exercise behaviour (e.g., Biddle & Batterham, 2015; Hardcastle et al., 2014). However, several researchers have questioned this assumption (e.g., Astorino & Thum, 2016b; Jung et al., 2016) and there has been a lack of research evidence to directly investigate this affect-behaviour relationship for interval exercise (Stork et al., 2017).

It has also been asserted that interval exercise is too complex and difficult for inactive people to complete and therefore may elicit perceptions of incompetence, low levels of enjoyment, self-esteem and self-efficacy; factors that could increase the potential for failure (Hardcastle et al., 2014). Further, it has been suggested that interval exercise requires high levels of effort, motivation, and self-regulation, and it is unlikely that people will continue to participate outside of the laboratory environment as a result (Hardcastle et al., 2014). Finally, some have contended that many interval exercise protocols are not truly time-efficient (Hardcastle et al., 2014) and that the problem is not whether people have time for exercise, but rather how they choose to spend their time (Biddle & Batterham, 2015).
1.3.2 The Debate: “The Supporters”

Supporters of interval exercise have asserted that interval exercise interventions can be used to help target areas of public and population health priority such as the prevention and treatment of various cardiometabolic diseases (e.g., Biddle & Batterham, 2015). This view is based on the idea that the reduced total time commitment, the inclusion of rest periods, and the relative intensities of the high-intensity work intervals, may make interval exercise more adaptable, practical, appealing, and enjoyable than continuous exercise (e.g., Jung, Bourne, & Little, 2014; Stork et al., 2017). It is believed that if interval exercise is time-efficient to complete and offers more appeal than traditional exercise, people may be more likely to participate in it (e.g., Astorino & Thum, 2016b; Jung et al., 2014).

Despite speculation that interval exercise may lower self-efficacy, enjoyment, and motivation, and may present challenges to self-regulation (Hardcastle et al., 2014), researchers have adopted theoretical perspectives to contend why this may not be the case (e.g., Astorino & Thum, 2016b; Del Vecchio et al., 2016; Jung et al., 2016). For instance, consistent with the principles of Social Cognitive Theory (SCT; Bandura, 1997), Jung et al. (2014) proposed that the intermittent nature of interval exercise breaks down the exercise into brief, manageable bouts, which may lead to several mastery experiences within a single interval exercise session and may consequently translate into enhanced exercise task self-efficacy. Further, the principle of exercise progression has been consciously utilized in interval exercise training studies whereby participants gradually increase the number of work bouts performed over the course of the training period (e.g., Jung, Bourne, Beauchamp, Robinson, & Little, 2015; Locke et al., 2018; Robinson et al., 2015). This approach allows for continued and successful interval exercise experiences and has been supported by
evidence of increases in interval exercise task self-efficacy following a 2-week HIIT intervention and at 24 weeks post-intervention (Locke et al., 2018). Although these findings provide initial support for the advocacy of interval exercise with respect to self-efficacy, further investigation of how increases in self-efficacy towards interval exercise is related to affect, enjoyment, and preferences for interval exercise, in comparison to other forms of exercise, is warranted (Jung et al., 2016).

Similar to how SCT has been used to refute previous claims about low self-efficacy toward interval exercise, other theoretical perspectives have been used to unpack claims about the enjoyment of interval exercise. In particular, some interval exercise research has used concepts from the Theory of Planned Behaviour (TPB; Ajzen, 1991) to help explain study findings and provide a better understanding of the role enjoyment may play in influencing psychological antecedents of exercise behaviour (e.g., Stork & Martin Ginis, 2017). In the context of exercise in general, enjoyment has been recognized as a predictor of positive exercise attitudes and behaviour (Martin Ginis et al., 2006; Rhodes, Fiala, & Conner, 2009; Stork & Martin Ginis, 2017) and a moderator of the intention-behaviour relationship (Rhodes & Quinlan, 2018). When people perceive a particular form of exercise as enjoyable, there is an increased likelihood that they will act on their intentions and engage in the exercise behaviour (Rhodes & Quinlan, 2018). In the context of interval exercise and in line with the principles of the TPB, it has been suggested that enjoyment of interval exercise predicts attitudes towards interval exercise, with attitudes mediating future intentions to engage in interval exercise (Stork & Martin Ginis, 2017). While it appears that the perceived enjoyment of interval exercise may be a key factor in determining how exercise attitudes and intentions translate into behaviour, there is currently a dearth of interval exercise research
investigating the relationship between these variables and, more specifically, how enjoyment of interval exercise may be related to subsequent interval exercise behaviour.

1.4 Improving the Pleasure and Enjoyment of Interval Exercise

Given that enjoyment and affect play important roles in the interval exercise debate, there is merit in determining ways to provide more positive interval exercise experiences that maximize levels of enjoyment and affect. Several evidence-based strategies such as music, motivational priming, and positive feedback have been applied to interval exercise, with the goal of enhancing people’s psychological responses. Such strategies have been shown to elicit more positive affect during, and greater enjoyment of, interval exercise (e.g., Brown, Teseo, & Bray, 2015; Jones, Tiller, & Karageorghis, 2017; Stork, Kwan, Gibala, & Martin Ginis, 2015; Tritter, Fitzgeorge, Cramp, Valiulis, & Prapavessis, 2013). For example, Stork et al. (2015) showed that the application of self-selected music during interval exercise has the potential to improve affect, enjoyment and performance of interval exercise for healthy active individuals. While early findings from studies implementing strategies to augment psychological responses to interval exercise are encouraging, there is considerable potential for more research on the topic in wake of the debate.

1.5 The Bottom Line: We Need More Psychological Research on Interval Exercise

With amassing evidence about the physiological and health benefits of interval exercise, there has been a growing interest in interval exercise from researchers, the general public, and the perspective of improving public health. This surge of interest has inevitably led to a compelling debate about whether interval exercise is a viable alternative to traditional exercise for largely inactive populations. This debate has included expression of conflicting perspectives in opinion articles regarding how people may respond psychologically to
interval exercise and the subsequent influence this may have on exercise behaviour. While these opinion articles have helped spark important discussion surrounding the debate, they have lacked a strong evidence base to support various claims.

For example, several researchers have noted that many of the claims about interval exercise made by Hardcastle et al. (2014) were not supported by scientific evidence (e.g., Astorino & Thum, 2016b; Jung et al., 2016). Sensibly, decisions regarding the public health promotion of interval exercise should be evidence-informed and more empirical data are required in order to make informed decisions and conclusions. Ultimately, if interval exercise should be recognized as a viable exercise alternative to traditional continuous exercise, a comprehensive analysis of the existing research should be conducted, and more research investigating the psychological responses and behavioural consequences of interval exercise among inactive individuals is needed.

1.6 General Purpose of Dissertation

The overarching purpose of this dissertation was to shed light on the ongoing debate by comprehensively evaluating the existing research evidence and examining the psychological and behavioural implications of engaging in interval exercise among physically inactive adults. First, a scoping review was conducted to provide a comprehensive synthesis of the research evidence regarding the psychological responses to interval exercise. Second, a mixed-methods experimental approach was used to study inactive participants’ psychological responses to acute bouts of interval and continuous exercise performed in a lab setting and their subsequent real-world exercise behaviour. Finally, a repeated-measures crossover design was used to study the effects of motivational music on the psychological, psychophysical and physiological responses to a practical interval exercise protocol among
insufficiently active adults. An overview of the objectives and hypotheses of each chapter is presented below.

1.7 Chapter Objectives and Hypotheses

1.7.1 Chapter 2

Objectives: The primary objective of the scoping review in Chapter 2 was to map the psychological outcomes that have been measured, the research methods used, and the results from published studies investigating psychological responses to interval exercise. The secondary objective was to identify key issues, considerations, and gaps in the literature in order to provide recommendations for future work in the area. Indeed, several of the issues, considerations, and gaps identified in Chapter 2 were used to inform the subsequent studies in Chapter 3 and Chapter 4.

1.7.2 Chapter 3

Objectives: The primary objective of the study described in Chapter 3 was to compare psychological responses (i.e., affect, arousal, enjoyment) to, and preferences for, acute sessions of MICT, HIIT, and SIT among a sample of inactive adults. The secondary objective was to investigate the relationships between acute psychological responses to lab-based sessions of MICT, HIIT, and SIT and participants’ subsequent exercise behaviour completed over a 4-week follow-up period. The tertiary objective was to use semi-structured interviews to develop a richer understanding of people’s experiences during and following completion of MICT, HIIT, and SIT sessions in the lab, and to provide novel insight into factors that may influence inactive people’s ability to engage in MICT, HIIT, and SIT on their own, outside of the lab.
Hypotheses: It was hypothesized that affective responses would be similar or more negative during HIIT and SIT in comparison to MICT, and the enjoyment of HIIT would be equal to, or greater than, MICT, while the enjoyment of SIT would be lower than HIIT or MICT. Further, it was predicted that participants would prefer HIIT the most, followed by MICT, and then SIT. Finally, it was hypothesized that in-task affective responses to lab-based MICT, HIIT, and SIT would be predictive of post-exercise enjoyment of and subsequent 4-week exercise behaviour for MICT, HIIT and SIT, respectively.

1.7.3 Chapter 4

Objective: The objective of the study described in Chapter 4 was to investigate the psychological (i.e., affect, arousal, enjoyment), psychophysical (i.e., perceived exertion), and physiological (i.e., heart rate, power output) effects of motivational music during performance of a practical SIT protocol among insufficiently active adults.

Hypotheses: It was hypothesized that the use of motivational music during SIT would lead to more positive affect, higher post-exercise enjoyment, and greater peak and mean power output when compared to two control conditions (an audio podcast and no audio condition). In addition, it was predicted that ratings of perceived exertion would not differ between the three conditions.

1.8 Summary

A scoping review and two controlled experimental laboratory-based studies were undertaken in order to contribute to the empirical literature that is needed to advance the debate regarding the viability of interval exercise for largely inactive populations. The affective responses to, enjoyment of, and preferences for interval exercise were evaluated across these studies in order to develop a better understanding of their potential roles for
influencing interval exercise behaviour. These studies are presented in the subsequent three chapters, followed by a general discussion summarizing how this dissertation has contributed to the literature on interval exercise, affect, enjoyment, the application of music to exercise, and exercise behaviour.
Chapter 2: A scoping review of the psychological responses to interval exercise: Is interval exercise a viable alternative to traditional exercise?

2.1 Background

Interval exercise generally refers to intermittent bouts of relatively high-intensity exercise separated by periods of recovery (Gibala, Gillen, & Percival, 2014). It is an infinitely variable form of exercise that has been experimented on by coaches and athletes interested in human performance for over a century (Billat, 2001). English language publications on physiological responses to this type of exercise date back to the early 1960s (I. Astrand, P. Astrand, Christensen, & Hedman, 1960). A renewed surge of interest in the topic over the past decade has advanced our understanding of physiological and health adaptations to interval exercise training in both healthy individuals and those with cardiometabolic diseases (Gibala et al., 2014; Weston, Wisløff, & Coombes, 2014). There is also growing interest from a broader public health perspective, given that interval exercise training can be a time-efficient exercise strategy to elicit adaptations typically associated with traditional endurance exercise training (Gillen et al., 2016). However, the psychological consequences and behavioural implications of engaging in interval exercise are less clear and have become the topic of vigorous debate (e.g., Biddle & Batterham, 2015).

For instance, although studies have reported that participants experience more negative affect during interval exercise than continuous exercise (e.g., Decker & Ekkekakis, 2017; Oliveira, Slama, Deslandes, Furtado, & Santos, 2013), studies have also reported that participants actually enjoy and prefer interval exercise just as much, if not more than, continuous exercise (e.g., Astorino & Thum, 2016a; Crisp, Fournier, Licari, Braham, & Guelfi, 2012a; Jung, Bourne, Little, 2014). Such seemingly contradictory findings have led to
discussion and debate as to whether interval exercise should be advocated in public health messages and strategies promoting physical activity. On the one hand, critics contend that interval exercise ‘cannot be a viable public health strategy as it will not be adopted or maintained by many people’ (Biddle & Batterham, 2015, p. 1). This position is based largely on the belief that most people will find interval exercise so unpleasant, that they will not adhere to it long-term (e.g., Biddle & Batterham, 2015; Hardcastle, Ray, Beale, & Hagger, 2014). On the other hand, supporters have argued ‘There is great potential for [interval exercise] interventions to contribute to addressing areas of public health priority, including prevention and treatment of Type 2 diabetes and cardiovascular disease’ (Biddle & Batterham, 2015, p. 3). This position is predicated on the notion that the intermittent nature and relative intensities of the high-intensity work periods make interval exercise more adaptable, practical, and tolerable than people may be led to believe; if exercise can be completed in less time and be relatively enjoyable overall, people may be more likely to adhere (e.g., Astorino & Thum, 2016b; Jung et al., 2014).

In addition, it has been suggested that a major benefit of interval exercise is that protocols can be readily adapted and numerous variations in protocol parameters are possible (e.g., Astorino & Thum, 2016b; Jung, Little, & Batterham, 2016). However, the debate over the viability of interval exercise is, in part, fuelled by inconsistencies in the interval exercise protocols implemented in studies and the terms used to characterize such protocols. Interval exercise protocols may vary in the total exercise duration, the intensity and total number of work bouts completed, and the length of work and rest periods (e.g., Cassidy, Thoma, Houghton, & Trenell, 2017; Weston et al., 2014). Varying protocols present a challenge when attempting to compare findings between studies that adopt different interval exercise
protocols. Further, several terms have been used to describe interval exercise and its various forms (e.g., intermittent exercise, high-intensity interval training, sprint interval training; see also Weston et al., 2014), which also complicates the interpretability of research findings. Thus, the use of different interval exercise protocols and terminology needs to be carefully considered when evaluating the interval exercise literature.

The debate has also been driven by conflicting theoretical perspectives on how people will respond psychologically to interval exercise. For instance, the dual-mode theory (Ekkekakis, 2003) postulates that individuals will experience a shift towards more negative affective responses during high-intensity exercise performed above the ventilatory threshold (VT), and such negative feelings may deter future exercise participation (e.g., Rhodes & Kates, 2015; Williams, Dunsiger, Jennings, & Marcus, 2012). According to the dual-mode theory, when individuals exercise at intensities beyond the VT, they experience a lack of oxygen, accumulation of lactate, increased respiration, and free nerve ending stimulation (Ekkekakis, 2003). Such physiological stress subsequently leads to stimulation of the affective centres of the brain (e.g., the amygdala), eliciting a negative affective response (Ekkekakis, 2003). Based on these tenets, it has been proposed that the high-intensity nature of interval exercise will likely elicit negative affective responses during exercise, and people may avoid participating as a result (e.g., Hardcastle et al., 2014). However, virtually all of the research to investigate the exercise intensity-affect relationship (Ekkekakis, Parfitt, & Petruzzello, 2011) and how affect can be used to predict exercise behaviour (e.g., Rhodes & Kates, 2015; Williams et al., 2012) has been conducted using continuous exercise protocols, rather than interval exercise protocols (see also Biddle & Batterham, 2015). As a result, it is
not clear how the results of these studies, and the predictions of dual-mode theory, generalize to interval exercise (see also Biddle & Batterham, 2015).

Social cognitive theories have also been used to formulate predictions regarding people’s psychological responses to interval exercise. In the general exercise literature, Social Cognitive Theory (SCT; Bandura, 1997) and the Theory of Planned Behaviour (TPB; Ajzen, 1991) conceptualize control over barriers (e.g., perceived lack of time) and exercise enjoyment as influencing key psychological antecedents of exercise behaviour (e.g., self-efficacy, attitudes; e.g., Kwan & Bryan, 2010a; Martin Ginis et al., 2006). Given that interval exercise may be time-efficient and enjoyable (e.g., Astorino & Thum, 2016b; Jung et al., 2014; Stork & Martin Ginis, 2017), some researchers have adopted social cognitive perspectives to generate hypotheses regarding self-efficacy and attitudinal responses to interval exercise. For example, consistent with the tenets of SCT, Jung et al. (2014) suggested that exercisers accumulate multiple mastery experiences when completing high-intensity work bouts during interval exercise, which may lead to improved exercise self-efficacy. Additionally, Stork & Martin Ginis (2017) have hypothesized that, consistent with the tenets of the TPB, enjoyment predicts attitudes towards interval exercise, which in turn mediate future intentions to participate in interval exercise. However, the lack of social cognitive-based research on this topic limits our current understanding of the processes and mechanisms that underpin the psychological responses to interval exercise.

The ongoing debate and conflicting theoretical perspectives on how people will psychologically respond to interval exercise highlights the need for a systematic synthesis and appraisal of research on this topic. Indeed, decisions regarding the public health promotion of interval exercise should be evidence-informed and not simply based on beliefs
about how people might behave or what they might prefer. A systematic and comprehensive review of the literature would help health psychologists determine the viability of interval exercise as a public health strategy. As such, the overarching purpose of this review was to map research evidence from primary peer-reviewed, published studies investigating psychological responses to participation in various forms of interval exercise. Our primary objective was to catalogue what psychological outcomes have been investigated in these studies, the research methods used, and the results. A secondary purpose was to identify issues, considerations and gaps in this body of literature in order to formulate recommendations for future research.

Given these objectives, coupled with the relative novelty of the study of psychological responses to interval exercise, a scoping review was determined to be the most appropriate approach for reviewing the literature. Scoping reviews aim to capture the relevant literature on a topic, regardless of the study design, and can be used to identify the parameters of, and the gaps in, the literature (Arksey & O’Malley, 2005). Other types of reviews such as meta-analyses or systematic reviews address more narrowly-focused research questions and would have been less appropriate given the wide variability in study designs (e.g., acute and training studies) and methodology (e.g., measurement, exercise protocols) in the current literature. Scoping reviews are more comprehensive and inclusive than other forms of reviews and allow for broader discussions about the state of the literature as well as the capacity for addressing important limitations. With research on psychological responses to interval exercise still in its infancy, it was considered prudent to try to capture all published research on the topic in order to achieve a comprehensive perspective on this body of literature and to formulate recommendations for future research.
2.2 Methods

The 5-stage methodological framework recommended by Arksey and O’Malley (2005) and recently updated by Daudt, van Mossel, and Scott (2013) was adopted for this scoping review.

2.2.1 Stage 1: Identifying the Research Question

The scoping review addressed the general question: ‘What is known from published research about the psychological responses to participating in various forms of interval exercise?’

2.2.2 Stage 2: Identifying Relevant Studies

A literature search strategy was developed by the first and senior authors (MJS, KAMG) in consultation with a library scientist (LEB). Examples of the search terms included: interval or intermittent training or exercise, sprint or high-intensity interval training or exercise, enjoy*, feeling*, arousal, exercise behavior?r*, attitudes, intentions. Multiple terms such as ‘interval,’ ‘intermittent,’ ‘sprint,’ or ‘high-intensity’ along with ‘exercise’ or ‘training’ were used in these searches in order to account for the varying terms used to describe interval exercise that exist in the literature. The complete search strategy is available in the supplemental material (Appendix A.1.). The first author (MJS) conducted separate searches of articles published from 1946 to November 16, 2016 in the following databases: MEDLINE, EMBASE, PsycINFO, and SPORTDiscus. All citations returned by the search criteria were exported to an online management system (RefWorks, ProQuest LLC, Michigan, USA). Duplicate articles were identified and removed from the database. Reference lists from articles and other related resources were scanned for any additional relevant articles.
2.2.3 Stage 3: Study Selection

The first author (MJS) and a research assistant (NP) scanned the title and abstract of each reference to determine if the study met the review inclusion and exclusion criteria. The inclusion criteria were: (1) any articles testing interval exercise protocols of any type or modality (e.g., cycle ergometer, treadmill, resistance exercise), lasting any study duration (i.e., acute or training studies) that (2) included any psychological outcome measure. Interval exercise was defined as ‘alternating periods of relatively intense exercise with periods of lower-intensity effort or complete rest for recovery’ (Gibala et al., 2014, p. S128).

Articles were excluded if: (1) protocols were specifically designed to replicate sport performance (e.g., 4x15min quarters of intermittent sprints), because sport protocols follow different parameters and work-to-rest ratios than traditional interval exercise; (2) interval exercise training was performed in combination with another form of exercise or intervention component (e.g., a training program consisting of interval exercise and resistance exercise or a diet or psychological intervention); (3) exercise behaviour (or adherence) was reported without evaluating a psychological measurement or predictor of exercise behaviour; and (4) ratings of perceived exertion (RPE) were the only psychological measure reported, and were used as an exercise intensity manipulation check, not an outcome measure. Further, (5) studies that had not undergone full peer-review (e.g., conference proceedings, posters, published abstracts, lay articles, proposed studies, dissertations, theses, reviews, commentaries, debates); (6) any non-human studies; and (7) studies published in languages other than English were excluded from this review. These criteria were deliberated by MJS, KAMG, and LEB throughout the search process and were modified as the nature of the literature became apparent. This iterative approach is consistent with recommendations that
‘the researcher may not wish to place strict limitations on search terms, identification of relevant studies, or study selection at the onset. The [scoping review] process is not linear but iterative’ (Arksey & O’Malley, 2005, p. 22). Although reviews, commentaries, debates and opinion articles were not included in the data charting, they were read to provide context on the literature (see Appendix A.2. for reference list of secondary research sources).

Reviewers were not blinded to the journals or study authors during the screening process. The first author (MJS) and the research assistant (NP) retrieved full articles for citations that met the inclusion/exclusion criteria and read each full text to determine its inclusion in, or exclusion from, the review. Authors LEB and KAMG were consulted to discuss any discrepancies and all were resolved through consensus. Articles that were excluded during the initial selection and full text screening procedure were noted, and reasons for exclusion were recorded. Please refer to Appendix A.3. (flow chart) for an overview of the flow of articles through the search process.

2.2.4 Stage 4: Charting the Data

The first author (MJS) extracted and charted the following data from each article: author(s), year of publication, participants sampled, study design, exercise protocol(s), exercise protocol(s) classification, and key psychological findings. The research assistant (NP) checked the extractions. The articles were not blinded during the extraction and charting process.

An exercise physiologist with expertise in interval training (MJG) and the first author (MJS) assessed the descriptions of the exercise protocols reported in each study. Following initial observation of the variability in exercise terminology used across studies, a decision was made to classify all exercise protocols in order to provide more consistent use of
terminology when describing study protocols. Consequently, interval exercise protocols were classified as either high-intensity interval training (HIIT), sprint interval training (SIT), or body-weight interval training (BWIT). HIIT was defined as relatively intense but submaximal efforts that generally elicit ≥80% of maximal heart rate (HRmax) and SIT defined as ‘all-out’ or ‘supramaximal’ efforts performed at a workload that elicits ≥100% of maximal oxygen uptake (VO₂max). These definitions were modelled after the recommendations of Weston et al. (2014) for defining HIIT and SIT. Protocols were defined as BWIT when body-weight resistance exercise was performed in a circuit type manner with short periods of recovery.

When continuous exercise protocols were also included in a study, these were classified as either moderate-intensity continuous training (MICT) or vigorous-intensity continuous training (VICT). Consistent with the American College of Sports Medicine’s (ACSM, 2014) recommendations, protocols performed at 46-63% of VO₂max (64-76% of HRmax) were classified as MICT and protocols performed at 64-90% of VO₂max (77-95% of HRmax) were classified as VICT. Not all studies reported intensity in terms of VO₂max or HRmax; thus, in some instances, classification was based on reported power output or other data. Any between-author discrepancies in classifications were discussed until consensus was achieved. The rationale for the classification of each study’s exercise protocol is available from the first author (MJS).

2.2.5 Stage 5: Collating, Summarizing and Reporting the Results

Data were summarized and reported based on themes emerging from the charting process.
2.3 Results

2.3.1 Articles Retrieved

The search yielded a total of 711 citations (see Appendix A.3.). After screening for inclusion/exclusion criteria, 42 published articles consisting of 39 different studies were included in the review (see Appendix A.4. for complete reference list of articles). Pertinent data extracted from each article are presented in Table 2.1.

2.3.2 Article Characteristics

One article was published in 2005 and all other articles were published between 2011 and 2016. Specifically, articles were published in 2005 (n=1), 2011 (n=2), 2012 (n=3), 2013 (n=4), 2014 (n=6), 2015 (n=10), and 2016 (n=16). Research was conducted in 12 countries, with a majority of the articles written by authors in Canada (n=9), and the United States (n=13). There was a total sample of 1258 participants across all studies, consisting of samples drawn from various populations (e.g., healthy, unhealthy, active, inactive). Thirty-two (76.2%) articles reported on the investigation of psychological outcomes as a primary focus, while in 10 (23.8%) articles, the psychological outcomes were a secondary focus. Twenty-nine (69.0%) articles reported on investigations of acute responses to interval exercise protocols, while 13 (31.0%) articles reported on the effects of multiple weeks (≥ 2 weeks) of interval training. Training studies lasted from 2 to 24 weeks in duration, with exercise session frequency ranging from 2 to 4 times per week. Articles reported on studies that implemented within-subject designs (n=25, 59.5%), between-subject designs (n=10, 23.8%), randomized controlled trials (n=4, 9.5%), pre-post designs (n=2, 4.8%), or a comparative study design (n=1, 2.4%). Four articles reported on studies that used various
methods (e.g., music, motivational priming, and positive/negative feedback) to improve psychological responses to interval exercise. All studies used quantitative methods.

2.3.3 Exercise Protocols

Of the 55 interval exercise protocols applied in the reviewed studies, 38 (69.1%) were classified as HIIT, 15 (27.3%) were classified as SIT, and 2 (3.6%) were classified as BWIT. Out of 29 continuous exercise protocols, 15 (51.7%) were classified as MICT and 14 (48.3%) were classified as VICT. There was considerable variation in the interval exercise protocols; for instance, there were wide variations in the durations and intensities of warm-up, cool-down, work and rest periods. The most frequently reported interval exercise protocol was a HIIT protocol consisting of 8-10 x 1-minute high-intensity bouts separated by 60-90s recovery periods (n=9). Regarding exercise modality, 29 studies conducted exercise protocols using cycle ergometers, 8 studies used treadmills, 2 studies utilized body-weight resistance, one study used an arm crank ergometer, and one study had participants running indoors on a wooden floor.

2.3.4 Psychological Measures

The psychological measures were synthesized into seven categories: affective responses, enjoyment, exercise-related social cognitions, cognition and executive function, health-related quality of life, exercise preference and behaviour, and other. A wide variety of measures were used to evaluate these constructs (see Appendix A.5. for a further breakdown of the psychosocial constructs). Overall, the Feeling Scale (FS; Hardy & Rejeski, 1989; n=13) and Physical Activity Enjoyment Scale (PACES; Kendzierski & DeCarlo, 1991; n=17) were the most frequently administered measures.
2.3.5 Key Psychological Findings

**Affective responses.** When describing studies that compared acute in-task affective responses between interval and continuous exercise, four articles reported that affect was more negative during HIIT or SIT when compared to VICT (Decker & Ekkekakis, 2017; Oliveira et al., 2013; Saanijoki et al., 2015) or MICT (Jung et al., 2014), four articles reported no significant differences in in-task affect between HIIT or SIT and MICT (Astorino & Thum, 2016a; Little, Jung, A. Wright, W. Wright, & Manders, 2014) or VICT (Jung et al., 2014; Kilpatrick, Greeley, & Collins, 2015), and one article (Martinez, Kilpatrick, Salomon, Jung, & Little, 2015) reported more positive affective responses during two HIIT protocols – HIIT(30s) and HIIT(60s) – when compared to VICT or HIIT(120s). Overall, these results generally suggest that affect is similar or more negative during interval exercise protocols in comparison to continuous exercise.

In studies that measured post-exercise affect, measurements were taken anywhere from immediately post-exercise up to 30-minutes post-exercise. Despite the variability in measurement points, the majority of these studies (n=6) found no differences in post-exercise affect between HIIT or SIT and continuous exercise. A total of three articles reported greater arousal responses during or following HIIT when compared to MICT (Tsukamoto et al., 2016a) or VICT (Oliveira et al., 2013; Saanijoki et al., 2015). One article (Muller et al., 2011) reported that negative mood disturbance was lower following an acute session of MICT compared to HIIT.

**Exercise enjoyment.** In articles that compared interval to continuous exercise, most articles reported that exercise enjoyment was similar or greater following interval exercise protocols in comparison to continuous exercise. Five articles reported that enjoyment was
greater following HIIT (Astorino & Thum, 2016a; Bartlett et al., 2011; Kong et al., 2016; Martinez et al., 2015; Ong et al., 2016) or SIT (Astorino & Thum, 2016a) conditions when compared to MICT or VICT. Ten articles (Cockcroft et al., 2015; Crisp et al., 2012a, 2012b; Foster et al., 2015; Jung et al., 2014; Kilpatrick et al., 2015; Little et al., 2014; Martinez et al., 2015; Oliveira et al., 2013; Sim, Wallman, Fairchild, & Guelfi, 2014) reported no significant differences in enjoyment between MICT or VICT conditions when compared to HIIT or SIT conditions. One article reported that enjoyment was greater following VICT than HIIT (Decker & Ekkekakis, 2017), and another reported that enjoyment was greater in the MICT condition than the SIT condition (Foster et al., 2015). Further, enjoyment of SIT or HIIT exercise was greater when participants listened to music in comparison to no music (Stork, Kwan, Gibala, & Martin Ginis, 2015), received autonomous motivational priming as opposed to neutral priming (Brown et al., 2016) or received self-efficacy enhancing (positive) feedback when compared to self-efficacy diminishing (negative) feedback or no feedback (Tritter, Fitzgeorge, Cramp, Valiulis, & Prapavessis, 2013).

**Exercise-related social cognitions.** One article reported that participants had greater task self-efficacy for, and were more likely to set intentions to engage in, HIIT or MICT in comparison to VICT after experiencing these exercise protocols (Jung et al., 2014). Similarly, another article (Boyd, Simpson, Jung, & Gurd, 2013) reported that participants had relatively high (≥7.9 out of 10) scheduling or task self-efficacy, and relatively positive intentions towards HIIT (≥5.2 out of 7) following 3 weeks of HIIT training, regardless of which HIIT protocol (100%Wmax or 70%Wmax intervals) they completed. In another training study, participants reported greater intentions to engage in BWIT once per week following 4 weeks of BWIT when compared to baseline intention measures (McRae et al.,
Conversely, one article (Langdon, Joseph, Kendall, Harris, & McMillan, 2016) reported no changes in participants’ motives for exercise participation following 9 weeks of BWIT, however these motives were fairly high to begin with and intentions towards BWIT were relatively positive post-training (3.95 out of 5). Acutely, autonomous motivational priming was reported to elicit more positive attitudes and perceived competence for HIIT exercise (Brown et al., 2016), listening to music during SIT led to more positive attitudes towards SIT exercise (Stork & Martin Ginis, 2017), and providing positive feedback while performing SIT led to higher satisfaction with SIT and mitigated a decline in SIT self-efficacy (that was observed following negative or no feedback; Tritter et al., 2013). Taken together, these results suggest that, for the most part, participants can develop more positive social cognitions towards interval exercise following participation in interval exercise protocols.

**Cognition and executive function.** Four articles reported improved Stroop task performance (an indicator of response inhibition) following acute HIIT exercise sessions (Alves et al., 2014; Lambrick, Stoner, Grigg, & Faulkner, 2016; Tsukamoto et al., 2016a, 2016b). One article (Lemmink & Visscher, 2005) reported no significant differences in reaction speed or response accuracy between participants who completed an acute session of HIIT exercise compared to a no exercise control group. Based on these preliminary findings, it appears that acute interval exercise, like aerobic exercise (e.g., Chang, Labban, Gapin, & Etnier, 2012), tends to be associated with performance improvements in tasks requiring executive function.

**Health-related quality of life.** Two articles reported that participants had improvements in perceived health following several weeks of either SIT or HIIT training.
(Freese et al., 2014; Shepherd et al., 2015). In contrast, two articles reported no changes in quality of life following 12 weeks of either HIIT or MICT training (Pattyn et al., 2016), or 12 months of HIIT training (Madsen, Arbo, Granøien, Walderhaug, & Moholdt, 2014). Based on the limited research on this outcome, it seems that improvements following interval exercise training were only found for perceived health measures, whereas studies that used aggregate measures of quality of life (that encompass a range of different sub-constructs) did not yield any changes.

**Exercise preference and behaviour.** In six studies, participants were asked to report their preferences for interval exercise in comparison to MICT. Five of these studies (Astorino & Thum, 2016a; Crisp et al., 2012a, 2012b; Jung et al., 2014; Ong et al., 2016) reported that participants clearly preferred HIIT or SIT over MICT. One study (Little et al., 2014) found that preferences for HIIT (6/10 participants) were comparable to MICT (4/10 participants). No studies found an overall greater preference for MICT or VICT over HIIT or SIT. These findings suggest a stronger participant preference for interval exercise protocols in comparison to MICT. One study (Wood et al., 2015) that investigated preferences between HIIT and SIT following a crossover design, found that participants had an equal preference (50%-50%) for HIIT and SIT.

Regarding exercise behaviour and adherence, one article reported greater adherence to HIIT (83%) than MICT (61%) training (Shepherd et al., 2015), while another reported equal training attendance rates for those in a HIIT, VICT(@VT), or VICT(80%Wmax) training program (Rizk et al., 2015). In Pattyn et al.’s (2016) study, 93.1% of those who underwent HIIT training and 89.6% of those who underwent MICT training were meeting physical activity guidelines during the 12-week training period and maintained these activity
levels for 1 year following cessation of the training intervention. These results suggest that interval exercise training programs can be adhered to, and may be conducive to continued physical activity behaviour.

2.4 Discussion

Through a scoping review, 42 articles were systematically identified that reported on psychological outcomes associated with interval exercise. The finding that nearly 40% of the articles were published in 2016 speaks to this rapidly emerging area of health psychology research. Our review catalogued and synthesized the extant literature, with a view to facilitating discussion of research gaps and important issues that need to be addressed in future studies.

Overall, affect and enjoyment have been the most frequently studied psychological outcomes in the interval exercise literature. Despite findings that affect tends to be similar or more negative during interval exercise than continuous exercise, the majority of studies showed that participants reported similar post-exercise affect across interval and continuous protocols. Interestingly, most studies reported that participants experienced equal or greater enjoyment of, and preference for, interval exercise protocols in comparison to continuous exercise. These are important findings that show people can enjoy interval exercise and may even prefer it over continuous exercise. This observation may seem surprising given that individuals’ potentially negative affective responses to interval exercise are thought to negatively impact their overall perceptions toward the exercise, subsequently reducing their likelihood of future participation (e.g., Biddle & Batterham, 2015; Hardcastle et al., 2014).

While there is evidence that in-task affective responses to acute continuous exercise may be predictive of future exercise participation and adherence (e.g., Kwan & Bryan,
2010b; Rhodes & Kates, 2015; Williams, et al., 2012), there is currently a scarcity of research to test whether this predictive relationship holds for interval exercise. It is possible that the intermittent nature of interval exercise complicates the way in which researchers can evaluate in-task affect and its subsequent effect on future interval exercise behaviour. It has been suggested that the three most meaningful aspects of people’s in-task affective responses to exercise may be: 1) the magnitude of the peak(s) of negative or positive affect, 2) the slope representing the rate of change in affect occurring during the exercise, and 3) affect experienced at the very end of the exercise session (Decker & Ekkekakis, 2017). Currently, however, it is unclear which of these specific components of people’s affective responses to interval exercise has the greatest influence on people’s enjoyment of, preferences for, and engagement in, interval exercise. Further investigation of this issue using dual-mode theory (Ekkekakis et al., 2003) and other hedonic theories is recommended.

The role of post-exercise affective responses to interval exercise should also be considered. While the majority of current evidence suggests that there is no clear relationship between post-exercise affect and subsequent exercise behaviour (Rhodes & Kates, 2015), some studies have detected a relationship (e.g., Annesi, 2005). Further, most research to date suggests that there is a rebound to more positive affective states following exercise regardless of exercise intensity (e.g., Ekkekakis, Hall, & Petruzzello, 2008) and, based on the findings in this review, there appears to be comparable post-exercise affective responses between continuous and interval exercise. Notwithstanding, it should be noted that, similar to in-task affect, the current evidence regarding the relationship between post-exercise affect and subsequent behaviour has been evaluated based on continuous exercise protocols (e.g., Rhodes & Kates, 2015). Thus, investigation into how people’s post-exercise affective
responses to interval exercise may influence their overall psychological experiences and future participation is warranted.

Social cognitions in relation to interval exercise have been examined in eight studies. While the results suggest that individuals can hold relatively positive beliefs about interval exercise, the wide range of social cognitions measured across studies makes it difficult to draw conclusions regarding the impact of interval exercise on these outcomes. Nevertheless, the extant literature provides a foundation for testing theory-driven hypotheses. For example, it has been suggested that the intermittent nature of interval exercise (breaking the exercise down into short work periods) may ‘potentially allow for multiple successful experiences, which in turn could serve to increase self-efficacy beliefs’ (Jung et al., 2014, p. 15). This SCT-based (Bandura, 1997) hypothesis is worthy of investigation. Moreover, several studies investigated people’s attitudes and intentions toward interval exercise, but none tested if these variables predict subsequent interval exercise behaviour. Further theory-driven research is encouraged to address questions regarding social cognitions, interval exercise and behaviour.

With regard to the effects of interval exercise on cognition and executive function, few studies have examined this issue, relative to the extensive body of research showing the effects of continuous aerobic exercise (e.g., Chang et al., 2012). Similarly, the volume of research on the effects of interval training on health-related quality of life pales in comparison to the body of research involving traditional aerobic exercise (e.g., Gillison, Skevington, Sato, Standage, & Evangelidou, 2009). Although the evidence is limited, the results suggest interval exercise may be associated with improved performance in tasks requiring executive function as well as improved perceived health. Further research is needed
to determine if interval exercise can elicit benefits in these outcomes comparable to the
effects observed with traditional endurance exercise.

The use of various methods designed to enhance people’s psychological responses to
interval exercise (music, motivational priming, and positive feedback) were found to improve
exercise enjoyment, attitudes and self-efficacy (Brown et al., 2016; Stork et al., 2015; Stork
& Martin Ginis, 2017; Tritter et al., 2013). Given that such strategies appear to enhance
individual experiences during interval exercise, they may in turn help motivate future
exercise behaviour. Continued research on this topic is warranted. In particular, future
research should investigate the longer-term behavioural implications of continued exposure
to such methods used before or during interval exercise.

2.4.1 Issues and Considerations Emerging in the Literature

In cataloguing the research on interval exercise and psychological outcomes, several
issues and considerations came to light, which have important implications for the
interpretation of the body of literature on this topic and for the conduct of future studies.

Use of exercise terminology. During the data charting process, all interval and
continuous exercise protocols were classified in order to minimize discrepancies in the use of
exercise terminology across the literature. For instance, in one study (Saanijoki et al. 2015),
interval training consisted of 4-6 x 30s ‘all-out’ bouts and was referred to by the authors as
HIIT. However, this protocol was re-classified as SIT, which is a more appropriate
representation of the exercise protocol described (Weston et al., 2014). Such clarifications
are important when making comparisons between studies using different interval exercise
classifications (e.g., Biddle & Batterham, 2015), because people’s experiences during one
form of interval exercise may not be the same as another. For example, people’s experiences
performing ‘all-out’ sprints on a cycle ergometer during SIT may be very different from their experiences completing squats and jumping jacks during BWIT. Thus, researchers should be aware of the inherent differences in the nature of HIIT, SIT and BWIT, and should carefully consider their use of terminology when labeling their interval exercise protocols.

Likewise, researchers should also give consideration to using terms such as MICT and VICT when describing continuous exercise protocols. Given the evidence that individuals experience more negative affective responses during continuous exercise performed at higher intensities compared to lower intensities (e.g., Ekkekakis et al., 2008), comparisons made between interval exercise and VICT are not equivalent to comparisons made between interval exercise and less-intense MICT. Adopting terms that provide a more accurate representation of exercise intensity may allow for more appropriate comparisons between studies.

**Consideration of specific exercise parameters.** Although a shift to more consistent exercise terminology will be helpful for distinguishing between general categories of interval and continuous exercise protocols, researchers still need to be aware of differences between specific protocols within those categories. For example, classifying protocols based on the nature of the exercise work periods would not account for variations in the total exercise duration, the total numbers of work bouts, or the length of work and rest periods. Given that these factors varied greatly across studies, at times it is even difficult to compare findings between studies using the same classification. For instance, in the study by Bartlett et al. (2011), the 50-minute HIIT protocol was comprised of a 7-minute warm-up, 6 x 3-minute high-intensity bouts separated by 3-minute active recovery periods, and a 7-minute cool-down. This contrasts with the more commonly implemented 24-minute HIIT protocol
comprised of a 2-minute warm-up, 10 x 1-minute high-intensity bouts separated by 1-minute recovery/rest periods, and a 3-minute cool-down. While both exercise protocols can be termed ‘HIIT,’ Bartlett et al. (2011)’s 50-minute HIIT protocol does not capture the time-efficiency that is characteristic of interval exercise. This issue highlights the importance of considering the specific characteristics of the exercise protocols being used in studies, before making sweeping conclusions about the effects of interval exercise.

Inconsistencies in relative durations of interval and continuous exercise. When investigating acute physiological responses to exercise, physiologists have suggested that, ‘effort and total duration of exercise are two critical parameters that should both be controlled when comparing continuous with intermittent exercise protocols’ (Nicolo, Bazzucchi, Haxhi, Felici, Sacchetti, 2014, p. 7). However, when attempting to draw conclusions about the psychological and behavioural implications of engaging in interval exercise in comparison to traditional endurance exercise, it can be argued that total exercise duration may not need to be controlled for. This trade-off seems to have contributed to the inconsistency in the relative durations of interval exercise protocols in comparison to continuous exercise across studies. While some studies matched total exercise duration between interval protocols and continuous exercise (e.g., Crisp et al., 2012a; Sim et al., 2014), others did not (e.g., Jung et al., 2014; Kong et al., 2016). This is problematic because the potential time-saving appeal of completing interval exercise in as little as 10-25 minutes is lost when an interval protocol duration is equated to that of a continuous exercise protocol, which is typically longer in duration (Gibala et al., 2014). As stated by Decker and Ekkekakis (2017), ‘since the main argument supporting the promotion of [interval exercise] in the domain of public health is its time efficiency…one would expect [interval exercise] sessions
to be compared to [continuous exercise] sessions that are longer’ (p. 8). Ultimately, variability in protocol durations across studies also makes it challenging to draw reliable conclusions about comparisons between interval and continuous exercise.

**Generalizability of findings and safety.** When considering the utility of interval exercise for public health, especially in sedentary or less healthy individuals, researchers should be cautious about drawing conclusions based on study findings from samples of healthy, active individuals (see also Biddle & Batterham, 2015; Decker & Ekkekakis, 2017). There has been some concern that interval exercise might be potentially harmful for older adults and people with chronic conditions (e.g., obese/overweight, cardiometabolic disease, and physically disabled), and this may influence psychological and health outcomes among such individuals. Several reviews and meta-analyses have considered the issue of safety and relative risk associated with interval exercise in higher risk populations, including those with cardiometabolic diseases (e.g., Cassidy et al., 2017; Levinger et al., 2015; Rognmo et al., 2012; Weston et al., 2014). A comprehensive assessment of this topic is beyond the scope of this review, but the general consensus seems to be that interval exercise (and HIIT in particular) can be a safe option for most people including those deemed at higher risk (Weston et al., 2014). Of course, appropriate medical screening and supervision is essential, and some forms of interval exercise are more suited than others for certain individuals. While the overall risk of an adverse incident appears to be relatively low, there is also some evidence of higher risk in response to interval as compared to continuous moderate exercise, particularly when expressed relative to total time spent exercising (Levinger et al., 2015; Rognmo et al., 2012). Levinger et al. (2015) recommended, ‘Patients who wish to perform [high-intensity interval exercise] should be clinically stable, have had recent exposure to at
least regular moderate-intensity exercise, and have appropriate supervision and monitoring during and after the exercise session’ (p. 53).

The wide range of studied populations (e.g., post-cardiac rehabilitation, coronary artery disease, obese/overweight, spinal cord injury) identified in this review is testament to the rise in studies investigating the benefits of interval exercise among inactive and less healthy individuals, and those at-risk for or living with chronic disease (see Table 1). Some researchers have even suggested that ‘unfit individuals may find short bouts of exercise less overwhelming and physically demanding than sustained exercise. As a result, they may be less likely to drop out and more likely to be adherent’ (Linke, Gallo, & Norman, 2011, p. 198). Further, SIT protocols (in addition to HIIT) have been shown to be efficacious among overweight boys, obese women, sedentary men and adults with a spinal cord injury (e.g., Astorino & Thum, 2016a; Crisp et al., 2012a, 2012b; Gillen et al., 2016; Kong et al., 2016). With more research investigating physically disabled, inactive, and/or less healthy participant samples, a deeper understanding of the potential of interval exercise to improve public health can be developed.

To date, there has been limited research comparing the differences in psychological responses to interval exercise between various demographic groups. For example, only 6 out of the 42 articles included in this review evaluated psychological responses to interval exercise among adolescents (ages 8-15 years). Although there is insufficient evidence to draw any firm conclusions, based on these six studies, it appears that adolescents experience similar psychological responses to interval exercise as adults (e.g., post-exercise enjoyment was similar between interval exercise and endurance exercise, with greater preferences for interval exercise; Cockcroft et al., 2015; Crisp et al., 2012a, 2012b). Further evaluation of the
differences in how various demographic groups (e.g., males vs. females, healthy vs. unhealthy, adults vs. adolescents, and able-bodied vs. physically disabled) respond psychologically to interval exercise is encouraged.

**Measurement of psychological outcomes.** Many different measures were used to evaluate the same psychological constructs, with some lacking theoretical underpinnings. For instance, while several articles reported on attitudes or intentions measurement items, only three of these articles (Brown et al., 2016; Langdon et al., 2016; Stork & Martin Ginis, 2017) based their measures on the tenets of the TPB (Ajzen, 1991) or Ajzen’s (2010) guidelines for developing measures of these constructs. Without a theoretical foundation, the validity of measures of social cognitions is questionable. In addition, certain TPB constructs (e.g., subjective norms, perceived behavioural control) were not measured in TPB-related studies, meaning that these constructs were not accounted for and the TPB was not tested in its entirety (see also Stork & Martin Ginis, 2017). Likewise, many of the studies that measured constructs of the SCT (Bandura, 1997) or TPB specifically focused on enhancing psychological responses to interval exercise (Brown et al., 2016; Stork et al., 2015; Stork & Martin Ginis 2017; Tritter et al., 2013). Further research is needed to evaluate the underlying psychological mechanisms that influence people’s perceptions of interval exercise without psychologically-enhancing methods.

Further, variability in the timing of measurements during and following acute exercise makes it difficult to compare findings across studies. For instance, some studies measured affect at the midpoint (e.g., Jung et al., 2014), during the last 15 seconds (e.g., Decker & Ekkekakis, 2017), or following (e.g., Oliveira et al., 2013) the high-intensity intervals. Additionally, several studies (e.g., Frazão et al., 2016; Wood et al., 2016) failed to
measure affect during recovery periods. Affect tends to fluctuate with high levels of sensitivity across work and rest periods, which may make it difficult for researchers to closely capture the true changes that occur throughout an acute exercise session (see also Decker & Ekkekakis, 2017). The accuracy of affect measurement during interval exercise could be improved by obtaining affect ratings ‘at the highest point of the “peaks” (i.e., at the end of recovery periods) and the lowest point of the “valleys” (i.e., at the end of the high-intensity intervals)’ (Decker & Ekkekakis, 2017, p. 8). Likewise, given that post-exercise enjoyment can increase over time from immediately following an interval exercise session up to 60-minutes post-exercise (e.g., Stork et al., 2015), it may also be important to consider when measures such as enjoyment are administered post-exercise.

Lastly, confounders also exist in how measures are administered. Many studies in this review presented multiple single-item scales (e.g., FS, RPE) in a side-by-side fashion when asking participants to report their acute responses to exercise. Thus, some common method variance may have occurred in these cases (see also Decker & Ekkekakis, 2017). Three possible ways future research can mitigate these potential biases would be to 1) familiarize participants with differences between each scale measure prior to experimental trials; 2) consistently provide instructions and remind participants about the different scales they will be responding to before each exercise session; and 3) prompt scale reports in a randomized order. Other confounding factors that exist in exercise science research in general (Helperin, Pyne, & Martin, 2015) and were found within the studies reviewed, include: the number or gender of experimenters present during data collection, instructions on how to perform exercise tasks, and the use of verbal encouragement. Researchers are encouraged to make efforts to control such factors.
2.4.2 Research Gaps and Recommendations for Future Research

While the rapid growth in the area of interval exercise research is valuable for expanding our understanding of the psychological aspects of interval exercise, it is important to note some of the significant gaps that currently exist in the literature. First, all of the studies included for review utilized quantitative methodologies. While quantitative research has yielded an initial appreciation of the psychological implications of interval exercise, it does not reveal everything we need to learn about the topic. Qualitative research would provide a richer understanding of people’s experiences, and the meaning they attach to these experiences (cf. Mayan, 2009), during and following completion of interval exercise protocols. In addition, qualitative methods would provide insight into the wide range of factors (e.g., barriers, motivation, and feasibility) that may influence people’s ability to engage in interval exercise in the long term (cf. Williams, Ma, & Martin Ginis, 2017).

Second, there is limited data on people’s adherence to interval exercise in the long term and in ‘real-world’ settings, outside of a supervised or laboratory environment. Preliminary evidence shows that individuals with prediabetes can independently adhere to HIIT training over the short term (4 weeks) and they do so at a higher rate than they adhere to MICT (Jung, Bourne, Beauchamp, Robinson, & Little, 2015). While these findings are encouraging, more research is required in order to determine if samples drawn from various populations can adhere to interval exercise over the long term. Further, in the vast majority of studies, researchers implemented the interval exercise protocols in labs, using specialized exercise equipment (cycle ergometers and treadmills). If interval exercise is to gain traction in public health contexts, it will be important to further develop and test the psychological benefits of protocols that do not require specialized equipment and can be easily
implemented in the ‘real world’, such as stair climbing or BWIT. For example, a recent study by Allison et al. (2017) demonstrated that 6 weeks of intense SIT stair climbing improved the cardiorespiratory fitness of untrained sedentary women. The authors concluded that ‘Stair climbing is likely to be an effective form of exercise given that public health physical activity initiatives are effective when they are lifestyle based’ (Allison et al., 2017, p. 305).

Moreover, SIT protocols that are completed using stairs may be more practical than running and cycling, as stair climbing has no associated costs, can be completed indoors or outdoors, and is accessible in private and public settings (Allison et al., 2017). While applications of interval exercise such as stair climbing present a promising avenue for promoting interval exercise in ‘real world’ settings, the psychological responses to such protocols still need to be evaluated.

Finally, the methodological issues highlighted in this review underscore the need for greater methodological rigour. More collaboration between the fields of health psychology and exercise physiology may help to address this issue. For instance, physiologists are adept at making decisions about the design and implementation of specific interval exercise protocols that have been shown to elicit important physical health benefits over several weeks of training, while psychologists are adept at selecting valid and reliable measures that can address theory-driven hypotheses. This suggestion echoes Jung et al.’s (2016) recommendations regarding the investigation of interval exercise: ‘We encourage that, rather than disputing without all necessary data, physiology- and psychology-related field experts engage in interdisciplinary research for a fair evaluation of this modality’ (p. 2).
2.4.3 Strengths and Limitations

This scoping review has several strengths including the use of rigorous, systematic methods for searching, evaluating and synthesizing the research evidence; the classification of interval and continuous exercise protocols administered across all studies; the identification of important issues, considerations and gaps in the literature; and the provision of vital recommendations for improving future research. However, there are limitations of this scoping review that should also be acknowledged. Classifying interval exercise protocols as HIIT, SIT, and BWIT is a somewhat rudimentary classification strategy that is helpful for distinguishing between interval exercise protocols, but does not account for all variations in exercise parameters. Further, although we classified continuous exercise protocols according to ACSM guidelines (ACSM, 2014), we do acknowledge that there were other possible methods of classification. Attempting to determine the actual exercise intensity participants were working at based solely on the information reported in the published articles proved to be a difficult task. Finally, we followed a traditional scoping review approach (Arksey & O’Malley, 2005), whereby all available published literature was considered, regardless of study quality. While this approach has the advantage of delineating the scope and parameters of the entire body of published research on a topic, it precludes the weighting of higher versus lower quality studies in formulating conclusions.

2.5 Summary

There is growing debate and conflicting theoretical viewpoints about how people psychologically respond to interval exercise. Through a systematic synthesis and appraisal of published research, this scoping review catalogued the psychological outcomes that have been studied, the research methods used, and the main results. Further, a much-needed
evaluation of published research was conducted to identify issues and gaps in this body of literature, and recommendations for future research were made. Affect and enjoyment were the most frequently studied psychological outcomes across studies. Although acute affective responses appear to be similar or more negative during interval exercise than continuous exercise, post-exercise assessments such as enjoyment of and preferences for interval exercise appear to be equal to or greater than continuous exercise. Moreover, early evidence indicates that individuals can hold relatively positive social cognitions towards interval exercise, and interval exercise may be associated with improvements in executive function and perceived health. From a psychological perspective, such findings support the viability of interval exercise as an alternative to continuous exercise. However, several issues must be resolved (e.g., use of terminology, consideration of specific exercise parameters, measurement of psychological outcomes) and gaps must be addressed (e.g., more qualitative research, investigation of ‘real-world’ behaviour, more interdisciplinary collaboration). Overall, the viability of interval exercise as a public health strategy remains contentious. More rigorous research that accounts for the stated limitations is needed in order to determine what potential role it may play as part of the solution to the problem of physical inactivity. While interval exercise may not be ideal for or preferred by all, it may be a viable option for many.
Table 2.1. Data extracted from each article included for review (N=42).

<table>
<thead>
<tr>
<th>Article</th>
<th>Participants</th>
<th>Study Design</th>
<th>Exercise Protocol Classification(s)</th>
<th>Key Psychosocial Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alves et al. 2014</td>
<td>22 healthy middle-aged adults (M=9, F=13; Mage=54y)</td>
<td>Acute; within-subject (cross-over)</td>
<td>HIIT</td>
<td>Time to complete Stroop colour word task sig. lower following HIIT in comparison to control; performance of Digit Span test not sig. different between HIIT and control</td>
</tr>
<tr>
<td>Astorino et al. 2016</td>
<td>30 healthy, sedentary women (Mage=23y; R=18-40y)</td>
<td>Training; RCT; 3x/week for 12 weeks</td>
<td>HIIT(80-90%Wmax); HIIT(60-80%Wmax)</td>
<td>Affect or arousal did not change over training or differ between groups; 96.4% (694/720) adherence to exercise sessions</td>
</tr>
<tr>
<td>Astorino &amp; Thum 2016</td>
<td>10 active adults w/spinal cord injury (M=9, F=1; Mage=33y; R=25-57y)</td>
<td>Acute; within-subject (cross-over)</td>
<td>HIIT; SIT; MICT</td>
<td>Enjoyment sig. greater following SIT and HIIT compared to MICT; preference for SIT (4/9) and HIIT (5/9) over MICT (0/9); affect similar between SIT, HIIT, and MICT, declined across time, and rebounded similar to pre-exercise levels 5mins post-exercise</td>
</tr>
<tr>
<td>Bartlett et al. 2011</td>
<td>8 healthy, recreationally active men (Mage=25y)</td>
<td>Acute; within-subject (cross-over)</td>
<td>HIIT; VICT</td>
<td>Enjoyment sig. greater following HIIT compared to VICT</td>
</tr>
<tr>
<td>Boyd et al. 2013</td>
<td>19 overweight/obese, sedentary men (Mage=23y; R=19-35y)</td>
<td>Training; between-subject 3x/week for 3 weeks</td>
<td>HIIT(100%Wmax); HIIT(70%Wmax)</td>
<td>Affect was sig. lower in HIIT(100%Wmax) than HIIT(70%Wmax) during 1st training session; no sig. difference in enjoyment, scheduling self-efficacy, task self-efficacy, or high-intensity exercise intentions between groups following training</td>
</tr>
<tr>
<td>Brown et al. 2016</td>
<td>42 healthy, recreationally active undergraduates (M=18, F=24; Mage=20y)</td>
<td>Acute; between-subject</td>
<td>HIIT</td>
<td>Autonomous motivation led to more positive attitudes towards HIIT and greater enjoyment and perceived competence post-exercise compared neutral priming condition; no sig. differences between conditions for task motivation during HIIT or intentions to engage in HIIT</td>
</tr>
<tr>
<td>Cockcroft et al. 2015</td>
<td>9 healthy pubertal boys (Mage=14y)</td>
<td>Acute; within-subject (cross-over)</td>
<td>HIIT; MICT</td>
<td>HIIT and MICT rated as equally enjoyable</td>
</tr>
<tr>
<td>Crisp et al. 2012a</td>
<td>24 overweight and normal weight boys (R=8-12y)</td>
<td>Acute; within-subject (cross-over)</td>
<td>SIT; MICT</td>
<td>No sig. differences in post-exercise enjoyment between MICT and SIT; Participants (9/9 normal weight, 7/9 overweight) indicated they preferred SIT more than MICT</td>
</tr>
<tr>
<td>Article</td>
<td>Participants</td>
<td>Study Design</td>
<td>Exercise Protocol Classification(s)</td>
<td>Key Psychosocial Findings</td>
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<tr>
<td>Crisp et al. 2012b</td>
<td>11 overweight boys (Mage=11y; R=8-12y)</td>
<td>Acute; within-subject (cross-over)</td>
<td>SIT(120s); SIT(60s); SIT(30s); MICT</td>
<td>Post-exercise enjoyment was similar for MICT, SIT(120s) and SIT(60s), but was sig. lower for SIT(30s) compared to MICT, SIT(120s), and SIT(60s); 9/11 participants rated SIT(60s) and SIT(120s) as the best, 1/11 rated MICT and 1/11 rate SIT(30s) as the best</td>
</tr>
<tr>
<td>Decker &amp; Ekkekakis 2017</td>
<td>30 obese, low-active women (Mage=39y; R=19-53y)</td>
<td>Acute; within-subject (cross-over)</td>
<td>HIIT; VICT</td>
<td>Affect more negative during HIIT than VICT; affect not sig. different post-exercise; post-exercise enjoyment greater for VICT than HIIT</td>
</tr>
<tr>
<td>Foster et al. 2015</td>
<td>65 relatively-sedentary individuals (M=23, F=42; Mage=20y)</td>
<td>Training; between-subject; 3x/week for 8 weeks</td>
<td>HIIT; SIT; MICT</td>
<td>SIT protocol sig. less enjoyable than MICT and HIIT; enjoyment of all protocols declined across duration of study</td>
</tr>
<tr>
<td>Frazão et al. 2016</td>
<td>58 healthy, active and insufficiently active men (Mage=25y)</td>
<td>Acute; comparative study</td>
<td>HIIT</td>
<td>Affective responses to first three work bouts similar between inactive and active men; inactive group had lower affective responses over time (bouts 4 to 10) than active group; inactive group displayed lower values of mean, lowest, and highest affective response</td>
</tr>
<tr>
<td>Freese et al. 2014</td>
<td>47 women at risk for metabolic syndrome (Mage=52y)</td>
<td>Training: RCT; 3x/week for 6 weeks</td>
<td>SIT</td>
<td>Six weeks of SIT increased perceived health, improved tension, depression, anger, vigour, fatigue and overall mood compared to no-exercise control</td>
</tr>
<tr>
<td>Jebali et al. 2013</td>
<td>19 healthy school-aged boys (Mage=11y)</td>
<td>Acute; within-subject (cross-over)</td>
<td>HIIT</td>
<td>Affect more positive during the Raqassa game in comparison to HIIT</td>
</tr>
<tr>
<td>Jung et al. 2014</td>
<td>44 healthy, sedentary adults (M=16, F=28; Mage=31y)</td>
<td>Acute; within-subject (cross-over)</td>
<td>HIIT; MICT; VICT</td>
<td>Affect more negative during and immediately following HIIT and VICT than MICT; affect not sig. different between HIIT and MICT 20mins post-exercise; no sig. difference in confidence to perform, and intentions to engage in, HIIT and MICT, but sig. higher than VICT; post-exercise enjoyment of HIIT and MICT same, but sig. greater than VICT; 24 participants preferred HIIT, 13 preferred MICT, 4 preferred VICT</td>
</tr>
<tr>
<td>Article</td>
<td>Participants</td>
<td>Study Design</td>
<td>Exercise Protocol Classification(s)</td>
<td>Key Psychosocial Findings</td>
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<tr>
<td>Kilpatrick et al. 2015</td>
<td>24 healthy, recreationally active undergraduates (F=12, M=12; Mage=22y)</td>
<td>Acute; within-subject (cross-over)</td>
<td>HIIT(@VT); HIIT(20%&gt;VT), MICT; VICT</td>
<td>Affect most negative during VICT and was sig. lower than MICT and HIIT(@VT) for all time points; affect during HIIT(20%&gt;VT) and HIIT(@VT) were never sig. lower than MICT; no sig. difference in affect between conditions immediately post-exercise; 10mins post-exercise, affect higher in HIIT(@VT) than other three conditions; enjoyment sig. less positive during VICT than all other conditions at all time points beyond 20% completion.</td>
</tr>
<tr>
<td>Kilpatrick et al. 2016</td>
<td>24 healthy, recreationally active undergraduates (F=12, M=12; Mage=22y)</td>
<td>Acute; within-subject (cross-over)</td>
<td>HIIT(@VT); HIIT(20%&gt;VT), MICT; VICT</td>
<td>Predicted RPE was highest in VICT; RPE increased from beginning to end of all trials; in-task RPE values were highest for VICT.</td>
</tr>
<tr>
<td>Kong et al. 2016</td>
<td>31 obese, sedentary women (Mage=21y)</td>
<td>Training; between-subject; 5 weeks (20 sessions total)</td>
<td>SIT; VICT</td>
<td>Enjoyment of SIT sig. greater than MICT in any of the 5 weeks during the intervention</td>
</tr>
<tr>
<td>Lambrick et al. 2016</td>
<td>20 healthy children (M=9, F=11; Mage=9y)</td>
<td>Acute; within-subject (cross-over)</td>
<td>HIIT; VICT</td>
<td>Stroop task performance was sig. greater 30mins following HIIT than MICT; Stroop task improved similarly for both HIIT and MICT 1min post-exercise.</td>
</tr>
<tr>
<td>Langdon et al. 2016</td>
<td>57 obese, overweight, normal weight and underweight undergraduate women (R=18-25y)</td>
<td>Training; pre-post; 2x/week for 9 weeks</td>
<td>BWIT</td>
<td>Intentions to participate in BWIT (measured post-training only) were relatively positive (3.95/5); fitness motives were only variable to sig. predict intentions towards BWIT.</td>
</tr>
<tr>
<td>Lee et al., 2016</td>
<td>12 overweight and obese adolescents (M=3, F=9; Mage=15y)</td>
<td>Training; pre-post; 3x/week for 4 weeks (12 sessions)</td>
<td>HIIT</td>
<td>Average attendance was 11/12 required sessions (92%); 10/12 (83%) participants reported high enjoyment of HIIT program; 7/12 (58%) reported that they enjoyed the HIIT program more than previous programs of aerobic, resistance, or combined exercise.</td>
</tr>
<tr>
<td>Lemmink &amp; Visscher 2005</td>
<td>16 recreational male soccer players (Mage=21y)</td>
<td>Acute; between-subject</td>
<td>HIIT</td>
<td>No sig. differences in reaction speed or response accuracy between HIIT and no-exercise control.</td>
</tr>
<tr>
<td>Little et al. 2014</td>
<td>10 overweight/obese, inactive adults; (M=2, F=8; Mage=41y)</td>
<td>Acute; within-subject (cross-over)</td>
<td>HIIT; MICT</td>
<td>Affect not sig. different between HIIT and MICT in-task; post-exercise enjoyment not sig. different between HIIT and MICT; overall 6/10 participants preferred HIIT and 4/10 preferred MICT.</td>
</tr>
<tr>
<td>Article</td>
<td>Participants</td>
<td>Study Design</td>
<td>Exercise Protocol Classification(s)</td>
<td>Key Psychosocial Findings</td>
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<tr>
<td>Madsson et al. 2014</td>
<td>49 patients who had completed cardiac rehabilitation (M=36, F=13; Mage=61y; R=42-78y)</td>
<td>Training; RCT; 12 months</td>
<td>HIIT</td>
<td>Self-reported and measured PA were similar between groups after 12 months; QoL was not sig. different between groups and did not change after 12 months in either group.</td>
</tr>
<tr>
<td>Martinez et al. 2015</td>
<td>20 overweight/obese, insufficiently active adults (M=11, F=9; Mage=22y)</td>
<td>Acute; within-subject (cross-over)</td>
<td>HIIT(30s); HIIT(60s); HIIT(120s); VICT</td>
<td>Affect declined during all trials; affect more positive in HIIT(30s) and HIIT(60s) than HIIT(120s) and VICT; in-task enjoyment declined in HIIT(120s) and VICT conditions only; post-exercise enjoyment was sig. greater following HIIT(60s) than HIIT(120s) and VICT</td>
</tr>
<tr>
<td>McRae et al. 2012</td>
<td>25 recreationally active female undergraduate students (Mage=20y)</td>
<td>Training; RCT; 4x/week for 4 weeks</td>
<td>BWIT; VICT</td>
<td>Enjoyment of BWIT increased following 4 weeks of BWIT; intentions to engage in BWIT 1x/week (but not 3x/week) improved after training; no sig. changes observed in control group</td>
</tr>
<tr>
<td>Muller et al. 2011, Oliveira et al. 2013</td>
<td>14 healthy young males (Mage=21y) and 15 young university males (Mage=24y)</td>
<td>Acute; within-subject (cross-over)</td>
<td>HIIT; MICT</td>
<td>Negative mood disturbance was sig. lower following MICT than HIIT; no sig. differences in Stroop task scores between conditions; Affect more negative and arousal higher during HIIT than VICT; affect not sig. different between HIIT and VICT 5mins post-exercise; post-exercise enjoyment was not sig. different between HIIT and VICT</td>
</tr>
<tr>
<td>Oliveira et al. 2015</td>
<td>14 young university males (Mage=24y)</td>
<td>Acute; within-subject (cross-over)</td>
<td>HIIT; VICT</td>
<td>RPE better predictor of affect than %VO2 and %HR for both VICT and HIIT; relationship between RPE and affect was sig. for both protocols, but was not sig. for %VO2 or %HR.</td>
</tr>
<tr>
<td>Ong et al. 2016</td>
<td>12 healthy pregnant women (Mage=35y)</td>
<td>Acute; within-subject (cross-over)</td>
<td>HIIT; MICT</td>
<td>Post-exercise enjoyment was sig. greater following HIIT than MICT; all 12 participants preferred HIIT over MICT.</td>
</tr>
<tr>
<td>Pattyn et al. 2016</td>
<td>200 coronary artery disease (CAD) patients (M=180, F=20; Mage=58y)</td>
<td>Training; between-subject; 3x/week for 12 weeks</td>
<td>HIIT; MICT</td>
<td>No change in PA behaviour from post-intervention to 1-year follow-up after both HIIT and MICT; 93.1% of HIIT and 89.6% of MICT participants were meeting PA guidelines; no sig. changes in QoL at follow-up for both HIIT and MICT</td>
</tr>
<tr>
<td>Article</td>
<td>Participants</td>
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<tr>
<td>Rizk et al. 2015</td>
<td>35 chronic obstructive pulmonary disease (COPD) patients (M=14, F=21; Mage=67y)</td>
<td>Training; between-subject; 3x/week for 12 weeks</td>
<td>HIIT; VICT(@VT) VICT(80%Wmax)</td>
<td>From pre to post acute exercise, positive affect increased and negative affect decreased across groups; no sig. differences in global affect scores post-exercise across groups; no sig. differences in mean attendance of training sessions across groups</td>
</tr>
<tr>
<td>Saanijoki et al. 2015</td>
<td>28 healthy, sedentary men (Mage=47y)</td>
<td>Training; between-subject; 2 weeks (6 sessions total)</td>
<td>SIT; VICT</td>
<td>Affect more negative and arousal higher during SIT than VICT; positive affect decreased acutely after SIT and remained same after VICT; negative affect higher during SIT than VICT; positive and negative affect both declined during the intervention, but was similar between groups</td>
</tr>
<tr>
<td>Shepherd et al. 2015</td>
<td>90 healthy, inactive university employees (M=30, F=60; Mage=42y)</td>
<td>Training; between-subject; 3x/week (supervised) for 10 weeks</td>
<td>HIIT; MICT</td>
<td>Adherence to HIIT sessions (83%) higher than MICT (61%); increased positive affect and decreased negative affect from pre to post training in both HIIT and MICT; no changes or sig. differences in life satisfaction between HIIT and MICT</td>
</tr>
<tr>
<td>Sim et al. 2014</td>
<td>17 overweight, inactive men (Mage=30y)</td>
<td>Acute; within-subject (cross-over)</td>
<td>SIT(100%VO₂max); SIT(170%VO₂max); MICT</td>
<td>Post-exercise enjoyment not sig. different between three conditions</td>
</tr>
<tr>
<td>Stork et al. 2015</td>
<td>20 healthy, moderately active undergraduate students (M=10, F=10; Mage=23y; R=18-30y)</td>
<td>Acute; within-subject (cross-over)</td>
<td>SIT</td>
<td>Affect and motivation decreased during SIT, with no sig. differences between music and no-music condition; post-exercise enjoyment increased over time and sig. greater in music than no-music condition</td>
</tr>
<tr>
<td>Stork &amp; Martin Ginis 2017</td>
<td>20 healthy, moderately active undergraduate students (M=10, F=10; Mage=23y; R=18-30y)</td>
<td>Acute; within-subject (cross-over)</td>
<td>SIT</td>
<td>SIT attitudes sig. more positive following music than no music condition; SIT intentions not sig. different between conditions; SIT attitudes and intentions relatively positive at baseline and did not sig. change at follow-up</td>
</tr>
<tr>
<td>Tritter et al. 2013</td>
<td>74 healthy, active university students (M=32, F=42; Mage=22y)</td>
<td>Acute; between-subject</td>
<td>SIT</td>
<td>High efficacy feedback group had sig. less of a decline in SIT self-efficacy from pre to post SIT than both low efficacy and no-feedback control groups; similar changes in affect throughout SIT exercise in all three groups; post-exercise enjoyment sig. greater in high efficacy than low efficacy or control; SIT satisfaction sig. higher in high efficacy and control than low efficacy</td>
</tr>
<tr>
<td>Article</td>
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<tr>
<td>Tsukamoto et al. 2016a</td>
<td>12 healthy males (Mage=23y)</td>
<td>Acute; within-subject (cross-over)</td>
<td>HIIT; MICT</td>
<td>Arousal sig. higher following HIIT than MICT, but not sig. different post-exercise; Stroop task performance sig. greater immediately post-exercise for both HIIT and MICT; improved Stroop task sustained 30min post-exercise in HIIT, but not MICT</td>
</tr>
<tr>
<td>Tsukamoto et al. 2016b</td>
<td>10 healthy males (Mage=23y)</td>
<td>Acute; within-subject</td>
<td>HIIT</td>
<td>Stroop task performance sig. improved from pre to post HIIT and was sustained for 40mins; following a 2nd HIIT session, Stroop task sig. improved from pre- to post-HIIT and was sustained for only 10 min</td>
</tr>
<tr>
<td>Tucker et al. 2015</td>
<td>14 recreationally active young males (Mage=27y; R=18-35y)</td>
<td>Acute; within-subject (cross-over)</td>
<td>HIIT(4x4min); HIIT(16x1min)</td>
<td>Post-exercise enjoyment not sig. different between the two HIIT protocols</td>
</tr>
<tr>
<td>Wood et al. 2016</td>
<td>12 recreationally active adults (M=8, F=4; Mage=24y)</td>
<td>Acute; within-subject (cross-over)</td>
<td>HIIT; SIT</td>
<td>Affect sig. decreased during HIIT and SIT and was not sig. different between protocols; 50% preferred HIIT, 50% preferred SIT</td>
</tr>
</tbody>
</table>


*Interval exercise protocols were classified as HIIT and SIT based on the recommendations of Weston, Wisloff, & Coombes (2014) and continuous exercise protocols were classified based on recommendations by the American College of Sports Medicine (ACSM, 2014); full details on the exercise protocols and rationale for the classification of each exercise protocol is available from the first author.

*Mean age and age ranges based on participants that were included for analysis.

*The Raqassa game protocol in this study was not classified as interval or continuous exercise.*
Chapter 3: Psychological and behavioural responses to interval and continuous exercise among inactive adults

3.1 Background

Physical inactivity and sedentary lifestyles have become a pervasive public health problem (Blair, 2009), with up to 85% of adults failing to meet physical activity guidelines (Colley et al., 2011). Identifying practical strategies to increase physical activity participation has become a public health priority (Blair, 2009). There is increasing recognition of interval exercise training as a time-efficient alternative to traditional endurance training to elicit physiological adaptations linked to improved health (e.g., Batacan et al., 2017; Gibala et al., 2014).

Interval exercise refers to intermittent bouts of relatively intense effort interspersed by periods of recovery within a single training session (Batacan et al., 2017). In studies involving healthy individuals and those at-risk for or living with cardiometabolic diseases, interval exercise training has been shown to induce meaningful physical health benefits similar to traditional moderate-intensity continuous exercise training (MICT), but in significantly less time (Batacan et al., 2017; Gibala et al., 2014). As a result, there has been growing public health interest in advocating interval exercise as a time-efficient exercise option for the largely inactive general population (Stork et al., 2017).

One of the most intense forms of interval exercise is sprint interval training (SIT; Gibala, Gillen, & Percival, 2014). Traditional SIT protocols consist of 4-6 x 30-s “all-out” bouts separated by 4 min of recovery, typically lasting ~20-25 min (Gibala et al., 2014). However, adaptations of traditional SIT protocols have since been implemented in order to provide variations of SIT that are more practical for sedentary individuals in terms of being...
shorter in duration and more feasible to complete (Metcalf, Babraj, Fawkner, & Vollaard, 2012). An example of a more practical SIT protocol consists of 3 x 20-s “all-out” bouts, separated by 2 min rest periods and lasts only 10 min in total, including a warm-up and cool-down (Gillen et al., 2014, 2016). Importantly, this SIT protocol has been shown to improve indices of cardiometabolic health to the same extent as MICT among inactive individuals (Gillen et al., 2016).

A somewhat less intense form of interval exercise is high-intensity interval training (HIIT; Gibala et al., 2014; Little, Safdar, Wilkin, Tarnopolsky, & Gibala, 2010). One of the most frequently studied HIIT protocols consists of 10 x 1-min bouts of exercise at ~85-90% heart rate maximum (HRmax), separated by 1-min periods of rest (Gibala et al., 2014; Stork et al., 2017). This HIIT protocol has been tested with inactive individuals (Batacan et al., 2017; Weston et al., 2014) and is still relatively time-efficient (24 min total exercise), but may be considered to be more tolerable than the “all-out” supramaximal intensity of a SIT protocol given that the work bouts are performed at a relatively lower intensity.

Although SIT and HIIT can both elicit important physiological adaptations comparable to MICT (Batacan et al., 2017; Gibala et al., 2014; Gillen et al., 2016; Weston et al., 2014), some scientists have questioned whether these interval exercise protocols should be promoted to the inactive population (Biddle & Batterham, 2015; Hardcastle et al., 2014). Consistent with the dual-mode theory (Ekkekakis, 2003), studies among inactive individuals have shown a decline in pleasure as exercise intensity increases and approaches maximal capacity (Ekkekakis, Parfitt, & Petruzzello, 2011). Thus, there is concern that inactive people may find the high-intensity nature of SIT and HIIT unpleasant, which may subsequently deter future exercise participation (Biddle & Batterham, 2015; Hardcastle et al., 2014).
Another apprehension is that people generally do not enjoy high-intensity exercise (Biddle & Batterham, 2015; Hardcastle et al., 2014), and enjoyment is an important predictor of exercise behaviour and adherence (Bartlett et al., 2011; Rhodes et al., 2009). It is important to note, however, that these concerns are largely based on research examining people’s responses to high-intensity continuous exercise (see also Stork et al., 2017). It is not clear if the predictions of dual-mode theory and the psychological responses to continuous exercise are the same as those for interval exercise (see also Stork et al., 2017).

Interestingly, most studies have reported that participants experienced equal or greater enjoyment of, and preferences for, interval exercise protocols in comparison to continuous exercise (Stork et al., 2017). For instance, a study of inactive adults found similar post-exercise enjoyment between the HIIT and MICT conditions, and overall preferences for HIIT (6/10 participants) were comparable to MICT (4/10 participants; Little, Jung, Wright, Wright, & Manders, 2014). In another study (Malik, Williams, Bond, Weston, & Barker, 2017), adolescent boys and girls reported higher levels of post-exercise enjoyment for HIIT than MICT, and 81% of participants preferred HIIT over MICT. Although these studies did not include a SIT protocol for comparison, another study found that recreationally active participants had relatively positive attitudes (M=5.03 out of 7) and intentions (M=4.80 out of 7) towards SIT after trying multiple SIT sessions for the first time (Stork & Martin Ginis, 2017). Together, such findings suggest that SIT and HIT may be more tolerable and enjoyable than one might expect (Stork et al., 2017).

It is not known, however, which interval exercise protocols are perceived most favorably by inactive individuals and may be conducive to subsequent exercise behaviour. Furthermore, despite suggestions that inactive individuals will not enjoy SIT (Hardcastle et
al., 2014), limited research to date has directly tested this proposition. Thus, the primary objective of this study was to compare the psychological responses (i.e., affect, arousal, and enjoyment) to acute sessions of MICT, HIIT, and SIT, and to determine which exercise protocol was preferred among a sample of inactive adults. Additionally, little is known about how people’s affective responses to interval exercise may relate to their enjoyment of, preferences for, and participation in, interval exercise (Stork et al., 2017). As such, the secondary objective was to investigate the relationships between psychological responses to acute lab-based sessions of MICT, HIIT, and SIT and participants’ subsequent exercise behaviour over a 4-week follow-up.

Another major gap identified in the scoping review conducted in Chapter 2 (Stork et al., 2017) was the absence of qualitative research on this topic. Qualitative research could provide a deeper understanding of people’s experiences during and following interval exercise, and the meaning they attach to such experiences (c.f. Mayan, 2009). Accordingly, a third objective was to use semi-structured interviews to develop a richer understanding of people’s experiences during and following completion of MICT, HIIT, and SIT sessions in the lab, and to provide novel insight into factors that may influence inactive people’s ability to engage in forms of MICT, HIIT and SIT on their own, outside of the lab.

In summary, this study is the first to: a) compare affect, enjoyment and preferences between MICT, HIIT, and SIT among inactive adults, b) examine the psychological responses to a more practical 3 x 20-s, 10-min SIT protocol, c) investigate the relationships between acute psychological responses to HIIT and SIT and real-world HIIT and SIT exercise behaviour, and d) take a qualitative approach to studying people’s initial lab-based
experiences with interval exercise and to determine how these experiences may influence their subsequent exercise behaviours completed in naturalistic environments.

**Hypotheses**

Based on a recent synthesis of research examining psychological responses to HIIT and SIT in comparison to MICT (Stork et al., 2017), we hypothesized that affect would be similar or more negative during HIIT and SIT in comparison to MICT, and the enjoyment of HIIT would be equal to, or greater than, MICT. Given the “all-out” nature of SIT, suggestions that SIT may be inappropriate for inactive individuals (e.g., Hardcastle et al., 2014), and findings from one training study (Foster et al., 2015), we anticipated that enjoyment would be lower for SIT than HIIT or MICT. Further, following similar rationale, we anticipated that participants would prefer HIIT the most, followed by MICT, and then SIT.

Consistent with findings from a study of continuous and interval exercise protocols (Greene, Greenlee, & Petruzzello, 2017), we hypothesized that in-task affect would be predictive of post-exercise enjoyment for each type of exercise, respectively. Based on evidence that in-task affective responses to continuous exercise are predictive of self-reported physical activity behaviour (Rhodes & Kates, 2015), we hypothesized that affective responses to a lab-based MICT protocol would predict participants’ subsequent MICT behaviour over a 4-week follow-up. In the absence of any research evaluating the relationship between in-task affective responses to HIIT or SIT and subsequent HIIT or SIT behaviour, we anticipated that, consistent with the hypothesis regarding MICT, in-task affect during HIIT would predict subsequent HIIT behaviour and in-task affect during SIT would predict subsequent SIT behaviour.
3.2 Methods

3.2.1 Methodological Overview

A concurrent embedded mixed-methods design was used (Creswell, 2009), which involved one phase of data collection (quantitative and qualitative data collected simultaneously), with priority given to the quantitative methods when designing the study. The qualitative methods were embedded (or nested) within the predominant quantitative method in order to address a different research question (i.e., objective three) and the mixing of the data from the two methods occurred at the interpretation phase. This mixed-methods approach was taken in order to gain broader perspectives from using two different methods as opposed to using one predominant method only (Creswell, 2009). More specifically, this approach was used to achieve triangulation (i.e., to compare the findings from different methods), complementarity (i.e., to elaborate or illustrate the findings of one method by use of another), initiation (i.e., to provide new insight into a certain phenomenon), and expansion (i.e., to use multiple methods to expand the range and scope of the study; Bryman, 2006). This methodology was underpinned by a pragmatic philosophy (i.e., prioritizing the research questions, using diverse approaches, and valuing objective and subjective knowledge; Morgan, 2007), which is consistent with the use of mixed-methods.

An important notion that underlies this mixed-method approach is that quantitative (i.e., generalizing approach) and qualitative (i.e., subjective and contextual approach) data provide different kinds of information (Creswell, 2009). As such, the quality criteria for each method of the study should be deliberated independently (e.g., Thrower, Harwood, & Spray, 2018). Nonetheless, the current study can be judged based on its relevance to the research questions, transparency, and rationale for utilizing mixed-methods (Bryman, 2006).
The quantitative component of this study aimed to address the primary and secondary objectives and included multiple manipulation checks (i.e., perceived exertion, heart rate) and outcome measures (i.e., affect, arousal, exercise enjoyment, exercise preferences) that were measured throughout the exercise trials and over the course of the five lab visits. The qualitative component of this study aimed to address the tertiary objective and consisted of multiple semi-structured interviews that were conducted at each of the five lab visits. The interview questions investigated several topics, including (but not limited to) general beliefs about MICT, HIIT, and SIT, physical and psychological experiences during acute MICT, HIIT, and SIT sessions, and barriers and facilitators to completing MICT, HIIT, or SIT on participants’ own free time.

3.2.2 Experimental Design

This mixed-methods study used a repeated measures crossover design, whereby each participant completed a total of three different exercise trials: MICT, HIIT, and SIT. The exercise testing order was randomized and counterbalanced using a 3 by 6 Williams Square design (Williams, 1946). Participant randomization was stratified by gender in blocks of 6. Each participant made a total of five visits to the lab over the course of approximately 8 weeks.

3.2.3 Participants

Based on previous literature that found effect sizes ranging from 0.50 to 1.40 for differences in affect and enjoyment between HIIT and continuous exercise conditions (e.g., Jung, Bourne, & Little, 2014; Martinez, Kilpatrick, Salomon, Jung, & Little, 2015), we estimated conservatively and powered for an effect of 0.60. Using a repeated measures analysis of variance (ANOVA) statistical test in G*Power 3 (Faul, Erdfelder, Lang, &
Buchner, 2007), a sample size of 27 was estimated to have 80% power to detect an effect of 0.6 (Cohen, 1992). Thirty-two inactive men and women (20 women) inexperienced with HIIT or SIT were recruited and enrolled in the study. Participants were excluded from the study if they had previously participated in the HIIT or SIT protocols administered in the study or had contraindications to exercise based on the Physical Activity Readiness Questionnaire (PAR-Q). As in previous interval exercise studies (e.g., Gillen et al., 2014), “inactive” was defined as ≤ 2 sessions/week of structured exercise (Rodgers & Gauvin, 1998) over the past 6 months. In addition to reporting low levels of activity, participants’ average maximal oxygen uptake (VO₂max) was 31.3±6.2 mL·kg⁻¹·min⁻¹, providing further evidence that this sample was relatively inactive. The McMaster Research Ethics Board approved the study protocol and participants were recruited through poster advertisements on campus and via email. All participants provided written informed consent and received an honorarium of $60 CAD in order to compensate them for their participation in the study.

3.2.4 Manipulation Checks

Perceived exertion. Borg’s (1998) CR-10 rating of perceived exertion (RPE) scale was used, which ranges from “Nothing at all” (0) to “Absolute Maximum” (10). The RPE scale is a valid and reliable measure of physical exertion during exercise (Borg, 1998).

Heart rate. Participants’ heart rate (HR) was continuously recorded throughout fitness testing and each of the exercise trials using a HR monitor (Polar S625X).

3.2.5 Main Outcome Measures

Affect. Hardy and Rejeski’s (Hardy & Rejeski, 1989) Feeling Scale (FS) was used to measure affective valence before, during and following the exercise trials. The FS is an 11-point bipolar, single-item scale that ranges from “Very Bad” (-5) to “Very Good” (+5) along
a displeasure-pleasure continuum. The FS has been established as a reliable and valid measure of exercise-related affective states (e.g., Hardy & Rejeski, 1989). It has been suggested that the three most meaningful affective responses people experience in-task during exercise are: 1) the magnitude of the negative or positive peaks, 2) the rate of change in affect, and 3) affect experienced at the very end of the exercise session (Decker & Ekkekakis, 2017; Stork et al., 2017). Considering that fluctuations in affect are typically observed in-task for HIIT or SIT protocols (e.g., Decker & Ekkekakis, 2017; Stork, Kwan, Gibala, & Martin Ginis, 2015) and the three exercise protocols in this study varied in total duration, we decided that the magnitude of the peak negative affect was the most appropriate in-task measure of affect for the current study. The peak negative in-task FS responses experienced by each participant during the exercise trials were calculated by determining each participant’s lowest FS score at any time point in-task for MICT, HIIT and SIT. The FS change scores for each participant during the exercise trials were calculated by subtracting each participant’s pre-task FS score from their peak negative FS score for MICT, HIIT and SIT.

Arousal. Svebak and Murgatroyd’s (1985) Felt Arousal Scale (FAS) was used to measure perceived activation (arousal) before, during and following the exercise trials. The FAS is a 6-point, single-item scale that ranges from “Low Arousal” (1) to “High Arousal” (6). The concurrent use of the FS and FAS strengthens their discriminant validity (Ekkekakis, 2013).

Note: Analyses were also replicated using the magnitude of the peaks of positive FS, the FS change score, and the end-of-task FS scores. The results were fundamentally the same with respect to each of these variables. Considering these non-differences and the factors raised here, the magnitude of the peak negative in-task FS was considered the most meaningful FS outcome to report.
**Exercise enjoyment.** Enjoyment of each exercise trial was measured immediately post-exercise using the Physical Activity Enjoyment Scale (PACES; Kendzierski & DeCarlo, 1991). The PACES was modified slightly such that each item was re-worded from the present to past tense (see also Stork et al., 2015; Stork & Martin Ginis, 2017). This scale has 11 negatively worded and 7 positively worded items that participants rated on a 7-point bipolar scale (from 1 to 7), indicating how they felt about the exercise they completed. The internal consistency was acceptable at each administration (Cronbach’s αs ≥ .94).

**Exercise preferences.** Following completion of all three exercise trials, participants were given a list of the three protocols and asked to “rank them (1, 2, 3) in order of preference with a ‘1’ indicating the exercise you liked the most.” They first completed these rankings with reference to the exercises performed in the lab, and then they ranked their preferences for activity to be completed during their own free time.

**Exercise behaviour.** Each participant was asked to complete an exercise log sheet (see Appendix B.1) and recorded exercise behaviour over the course of 4 weeks. Participants were instructed to record any daily exercise activities they engaged in and the modality they used, and to classify each aerobic activity as either MICT, HIIT, or SIT. Participants were asked to refer to the following definition of “exercise” while reporting answers to any questions: “A planned, structured, and repetitive bodily movement done to improve or maintain one or more components of physical fitness” (US Department of Health and Human Services, 1996). This definition of exercise, along with brief descriptions of MICT (“continuous moderate intensity”), HIIT (“10x1-min high-intensity bouts, 1-min rest between”), and SIT (“3x20-s ‘all-out’ bouts, 2-min rest between”), were provided at the bottom of the log sheets. Log-sheet data were used to calculate the frequency of MICT, HIIT.
and SIT exercise sessions enacted by each participant over a 4-week period. Exercise sessions were reviewed and coded for accuracy and exercise that was not characteristic of either of the three types of protocols were coded as “other” (e.g., a game of soccer, rock climbing, etc.) and were excluded from the analyses. The number of sessions of each type of exercise was compared, rather than the number of minutes spent on each type of exercise, given that HIIT and SIT are typically performed for shorter durations than MICT.

### 3.2.6 Protocol

**Semi-structured interviews.** At each of their five visits to the lab, participants were involved in semi-structured interviews that were recorded using an audio recording device (Sony ICD PX333 Digital Voice Recorder) and lasted a total of approximately 20 to 40 mins in duration across all interviews. While the use of semi-structured interviewing allows for pre-determined interview questions to guide the discussion, it also provides participants with some freedom to express themselves using open-ended questions (Sparkes & Smith, 2013).

The complete set of interview questions can be found in Appendix B.2. At visit 1, the interview questions were used to explore participants’ general beliefs about MICT, HIIT, and SIT prior to beginning the study. The interviews following each exercise trial (visits 2-4) were designed to capture participants’ physical and psychological experiences of the acute exercise sessions, and the meaning they attached to these experiences. Following visit 4, participants were involved in an additional interview in order to compare and contrast their experiences completing MICT, HIIT, and SIT in the lab, and to determine which exercise type(s) they intended to participate in during their own free time in the subsequent 4 weeks. A final set of interviews were conducted at visit 5 in order for participants to discuss and reflect upon their experiences exercising on their own time, outside of the lab setting.
Baseline testing (visit 1). Following confirmation of eligibility and providing written informed consent, participants completed their baseline semi-structured interviews. Participants then performed an incremental VO$_2$max test on an electronically braked cycle ergometer (Lode Corival, Groningen, The Netherlands). Following a 1-min warm up at 50W resistance, the resistance on the cycle ergometer was automatically increased by 1W every 2 seconds until volitional exhaustion or the point at which the participants’ pedal cadence fell below 50 RPM. A metabolic cart with an on-line gas collection system (Medisoft Ergocard) was used to collect oxygen consumption and carbon dioxide production data. VO$_2$max was calculated using the highest average oxygen consumption over a 15-s period. In addition to measuring VO$_2$max, this baseline fitness test was also used to assess maximal power output in Watts (Wmax) and HR$_{max}$ in order to determine individualized training intensities.

Exercise trials (visits 2-4). All three exercise trials included a 2-min warm-up at 50W and a 3-min cool-down at 25W, and were completed using the same cycle ergometer (Lode Corival, Groningen, The Netherlands). The cycle ergometer was set up so participants were directly facing a wall on which the three measurement scales were posted. The scales were color-coded to clearly differentiate between each and minimize common-method variance (see Stork et al., 2017). During the rest periods of HIIT and SIT, participants were given the option to completely rest or pedal very lightly, without physically exerting themselves any more than a 1 (“very weak”) on the RPE scale. For all three protocols, participants were asked to remain seated on the bike at all times, including work bouts and rest periods. Following the cool-down, participants were asked to remain in the lab for 20 min. MICT protocol. Participants completed 45 min of continuous cycling at 35% Wmax in order to elicit ~70-75% HR$_{max}$ (50 min total exercise; Gibala et al., 2014; Weston et al.,
2014) and were prompted to report their RPE, FS, and FAS scores before, during (at 5, 10, 15, 20, 25, 30, 35, 40 and 42.5 min), and immediately following the MICT work period, and during the cool-down. **HIIT protocol.** Participants completed 10 x 1-min bouts of exercise at 70% Wmax in order to elicit ~85-90% HRmax, separated by 1-min periods of rest (24 min total exercise; Gibala et al., 2014). Participants were prompted to report RPE, FS, and FAS before, during (immediately following each of the work bouts and during the last ~20s of the rest periods), and immediately following the HIIT protocol, and during the cool-down. **SIT protocol.** Participants completed 3 x 20-s “all-out” sprints, separated by 2-min periods of rest (10 min total exercise; Gillen et al., 2014, 2016). These “all-out” sprints were performed with an applied resistance added to the cycle ergometer, calculated as 5% of body weight (Gillen et al., 2016). Participants were prompted to report RPE, FS, and FAS before, during (immediately following each of the sprint bouts and during the last ~40s of the rest periods) and immediately following the SIT protocol, and during the cool-down. Participants were prompted to report RPE, FS, and FAS ~20s later for the SIT than HIIT protocol because the rest periods were longer and to allow time for verbal prompting leading into the 20-s “all out” sprints. This was also done in order to ensure participants were performing the sprints at the desired “all out” intensity.

Reports of RPE, FS, and FAS were prompted immediately following the work bouts for both the HIIT and SIT protocols due to logistical constraints with collecting scale responses during “all-out” and high-intensity cycling efforts. At these time points, participants were carefully instructed to report how they “felt during the exercise” bouts. At all other time-points (including rest periods), participants were instructed to indicate how they “feel right now.” Participants were reminded of these explicit instructions prior to each
exercise trial. Participants were also prompted to report FS and FAS and filled out the PACES immediately following each exercise trial (following cool-down), and were prompted to report FS and FAS at 10- and 20-min post-exercise. A visual representation of the MICT, HIIT, and SIT protocols is presented in Figure 3.1. Finally, the same set of semi-structured interviews were conducted at the end of each exercise trial visit.

Each exercise trial was scheduled at least 72 hours apart and most trials were completed about 7 days apart ($M=7.07$, $SD=2.45$ days). Participants were instructed to maintain consistent dietary and sleep habits and to avoid any physical activity for the entire day of their visits to the lab. In order to control for diurnal variations, participants were scheduled at approximately the same time of day for their exercise trials. Participants were made aware of the exercise protocol to be completed when they arrived at the lab. In order to control for motivational influence, the same scripted set of instructions were provided throughout each exercise trial by the same experimenter (MJS). One male experimenter (MJS) and one female volunteer were present for all exercise trials.

Following their final exercise trial (visit 4), participants completed the exercise preferences measures. Next, participants completed an additional set of semi-structured interviews. Finally, participants were given the exercise log sheets and instructions. Participants were encouraged to try variations of any of the three exercise protocols completed in the lab using any modality (e.g., biking, running, swimming), but were reminded that they were not obligated to do so. Two weeks later, participants were sent an email reminder to fill out their log sheets.

**Follow-up visit (visit 5).** Four weeks later, participants returned to the lab, submitted their completed log sheets and the final set of semi-structured interviews were conducted.
Finally, participants were debriefed, and remunerated for their participation in the study.

3.2.7 Quantitative Analysis

A separate one-way repeated measures ANOVA was conducted to assess differences between the MICT, HIIT, and SIT conditions for each of the six outcome measures (i.e., RPE, HR, FS, FAS, PACES, and exercise behaviour). Chi-squared tests and Friedman’s ANOVAs were used to determine differences in exercise preferences. When sphericity was violated, the Greenhouse-Geisser correction was applied (Field, 2013). Significant main effects were followed by post hoc pairwise comparisons using Bonferroni corrections in order to account for multiple comparisons. The magnitude of the observed effects were calculated as standardized Cohen’s $d$s (Cohen, 1992) and uncertainty in the estimates were reported as 95% confidence intervals using Hopkin’s (Hopkins, 2017) spreadsheet for repeated measures crossover designs. The effects were interpreted according to Cohen’s (Cohen, 1992) conventions (0.2 = small, 0.5 = medium, 0.8 = large).

Pearson and Spearman’s correlation coefficients were computed in order to determine the relationships between affect, enjoyment, exercise preferences, and exercise behaviour. One-tailed tests were used due to the directionality of the hypotheses, and Spearman’s rho was used instead of Pearson’s correlation coefficient for rank-ordered variables (i.e., exercise preferences; Field, 2013). All analyses were initially conducted to test for the potential moderating effects of gender. No significant differences were found, so data were collapsed across men and women for the final analyses. SPSS version 21.0 was used for all analyses, and significance was set at $p<0.05$. 
3.2.8 Qualitative Analysis

A thematic analysis of the interview transcripts, as outlined by Braun & Clarke (2006) and Braun, Clarke, & Weate (2016), was conducted using a six-stage process. The thematic analysis was guided by an abductive approach, as both inductive and deductive approaches were used. This approach was undertaken in order to identify main patterns in the data without restriction to a pre-existing coding scheme or restriction to a prior framework, while also acknowledging that the theoretical background of the first author (MJS) may have influenced the coding and theming process.

For the first phase, the interviews were transcribed verbatim as soon as possible following the data collection period. The first author (MJS) then immersed themselves in the transcripts by reading through them thoroughly and taking notes on initial patterns and meanings, and coding ideas within the data. In particular, notes were taken for each participant’s individual thoughts, feelings, and experiences discussed over the course of his or her five lab visits. In the second phase, the first author (MJS) generated codes from the data in a meaningful way by identifying points of interest in the transcripts and important features of the data. The third author (TLW) reviewed the initial and final codes in order to act as a critical friend in the analysis process. Coding was completed in this manner, as a critical friend can be used provide critical feedback on the data analysis and writing process by encouraging exploration and reflection of alternative explanations and interpretations (Smith & McGannon, 2017; Williams, Ma, & Martin Ginis, 2017).

The third phase consisted of the first author (MJS) sorting the codes into potential sub-themes and themes, gathering all relevant coded data extracts, and organizing such codes based on overarching patterns. A collection of initial themes and sub-themes was identified at
this stage. At the fourth stage, themes were refined and combined into larger themes following review of the entire data set. At the fifth stage, the themes were defined and refined in order to identify what aspect of the data each theme captures and to ensure the themes were suited to the overarching research question. This was an iterative process that concluded at the end of the writing phase, during which slight adjustments were made to the theme names. The final names of the themes were decided on by ensuring they meaningfully reflected the essence of each theme. Finally, the sixth phase consisted of writing up the report in a coherent and logical way that provided an interesting and purposeful account of the story told by the data, both within and between themes.

3.3 Results

Two female participants withdrew from the study unexpectedly (one due to illness and another for an undisclosed reason) and their data were not included in the analyses. Thus, 30 participants (18 women) completed the study and their characteristics are presented in Table 3.1. Two participants had missing exercise log data; one male participant did not return the log and one female reported an extended illness. This same male participant failed to return to the lab for his final visit and therefore had missing visit 5 interview data.

3.3.1 Quantitative Results

The magnitude of the observed effects (d) and 95% confidence intervals based on comparisons between MICT, HIIT, and SIT for RPE, HR, FS, FAS, PACES, and exercise behaviour are presented in Table 3.2.

Manipulation Checks

Manipulation checks verified that participants were exercising at the intended training intensity for each protocol. Mean RPE during the work periods differed across trials, F(2,
RPE differed between all three conditions (ps<0.01) with RPE being lowest during MICT (M=4.06, SD=1.68), higher during HIIT (M=6.63, SD=1.35) and highest during SIT (M=7.81, SD=1.52; ds=0.80-2.28). Mean percentage (%) of HRmax during the work periods also differed across trials, F(2, 58)=69.16, p<0.01, η_p^2=0.71. %HRmax differed between all three conditions (ps<0.01) with %HRmax being lowest during MICT (M=77.68%, SD=5.64), higher during SIT (M=84.02%, SD=5.64), and highest during HIIT (M=89.30%, SD=3.97; ds=1.06-2.32). Mean HR over the entire exercise protocols were 76.39±5.65%, 84.74±4.54%, and 76.83±5.75% of HRmax for MICT (50min), HIIT (24min), and SIT (10min), respectively. The work periods of the exercise trials were performed at a mean of 68.50±13.33W for MICT, 137.00±26.67W for HIIT, and 314.37±87.30W for SIT. During SIT, participants performed “all-out” efforts at a variable power output corresponding to a mean of 158.71±18.96% of Wmax over the three sprint intervals.

**Main Outcome Measures**

**Affect.** The peak negative FS responses experienced in-task differed across the exercise trials, F(2, 58)=8.67, p<0.01, η_p^2=0.23 (see Figure 3.3). The peak negative FS for HIIT (M=-1.47, SD=2.30) was more negative than for MICT (M=0.27, SD=1.76; p<0.01, d=0.82). No statistically significant differences in negative FS peaks were detected between MICT and SIT (M=-0.80, SD=2.20; p=0.07, d=0.52) or HIIT and SIT (p=0.34, d=0.29). However, a medium-sized effect was found between MICT and SIT (d=0.52, 95% CI [0.07, 0.97]), suggesting that peak negative FS was more negative for SIT than MICT (see Table 3.2). FS ratings declined during all three exercise trials. Specifically, the FS change scores differed across the exercise trials, F(2, 58)=8.30, p<0.01, η_p^2=0.22. The FS change score for
HIIT \((M=-3.80, SD=2.91)\) was greater than for MICT \((M=-1.83, SD=2.00; \ p<0.01, \ d=0.77)\).

No statistically significant differences in FS change scores were detected between MICT and SIT \((M=-2.73, SD=2.52; p=0.19, \ d=0.39)\) or HIIT and SIT \((p=0.11, \ d=0.38)\). However, small to medium-sized effects were found between MICT and SIT \((d=0.39, 95\% \ CI [-0.02, 0.80])\) and between HIIT and SIT \((d=0.38, 95\% \ CI [0.03, 0.74]),\) suggesting that affect may have declined in-task to a greater extent during SIT than MICT and during HIIT than SIT (see Table 3.2).

FS ratings immediately (0-min) post-exercise differed across the exercise trials, \(F(2, 58)=5.02, \ p=0.01, \ \eta_p^2=0.15\). At 0-min post-exercise, FS was more positive for MICT \((M=2.30, SD=1.53)\) than for SIT \((M=1.23, SD=1.94; \ p<0.05, \ d=0.59)\). No differences in FS 0-min post-exercise were detected between MICT and HIIT \((M=2.17, SD=1.42; \ p=1.00, \ d=0.09)\) or HIIT and SIT \((p=0.09, \ d=0.53)\). However, a medium-sized effect was found between HIIT and SIT \((d=0.53, 95\% \ CI [0.05, 1.01]),\) suggesting that FS 0-min post-exercise was more positive for HIIT than SIT (see Table 3.2). There were no differences in FS scores pre-task or 10- and 20-min post-exercise across the three exercise trials \((ps>0.05, \ ds=0.02-0.24)\).

Arousal. FAS during the work periods differed across the exercise trials, \(F(1.42, 41.18)=15.31, \ p<0.01, \ \eta_p^2=0.35\) (see Figure 3.4). FAS during the work period of MICT \((M=2.86, SD=0.90)\) was lower than during the work periods of HIIT \((M=3.84, SD=1.28; \ p<0.01, \ d=0.89)\) and SIT \((M=3.92, SD=1.28; \ p<0.01, \ d=0.93)\). No differences in FAS were detected between the work periods of HIIT and SIT \((p=1.00, \ d=0.06)\). FAS scores were not different pre-task or 0-min, 10-min, and 20-min post-exercise across the three exercise trials \((ps>0.05, \ ds=0.03-0.34)\).
**Exercise enjoyment.** There were no differences in participants’ PACES between the three exercise protocols immediately post-exercise (mean scores: MICT=83.70±19.20, HIIT=84.43±18.47, SIT=81.63±18.78), F(2, 58)=0.27, p=0.76, \( \eta_p^2=0.01 \).

**Exercise preferences.** Based on the #1-ranked (i.e., most preferred) protocol participants completed in the lab, 13/30 (43.3%) participants preferred HIIT, 10/30 (33.3%) preferred MICT, and 7/30 (23.3%) preferred SIT, with no differences in the frequency of #1 rankings, \( \chi^2(2)=1.80, p=0.41 \). Further, there were no differences in overall rank-ordered (#1-3) exercise preferences (in lab) between the three exercise protocols, \( \chi^2(2)=0.20, p=0.94 \).

Based on #1-ranked protocols participants would prefer to complete on their own free time, 15/30 (50.0%) preferred MICT, 8/30 (26.7%) participants preferred HIIT, and 7/30 (23.3%) preferred SIT, with no differences in the frequency of #1 rankings, \( \chi^2(2)=3.80, p=0.15 \).

Further, there were no differences in overall rank-ordered (#1-3) exercise preference (free time) between the three exercise protocols, \( \chi^2(2)=3.27, p=0.21 \).

**Exercise behaviour.** Participants exercised using a variety of modalities such as running outside, stairclimbing, swimming, biking, and using a treadmill, and completed a mean total of 11.04±5.29 sessions of MICT, HIIT, and SIT exercise combined over 4 weeks. The frequency of exercise sessions completed over 4 weeks differed between the three exercise types, F(1.53, 41.38)=10.77, p<0.01, \( \eta_p^2=0.29 \). Participants completed more MICT sessions (\( M=6.11, SD=4.12 \)) than SIT sessions (\( M=1.39, SD=1.85; p<0.01, d=1.34 \)). No statistically significant differences in the number of sessions of MICT versus HIIT (\( M=3.54, SD=4.23; p=0.16, d=0.56 \)) or HIIT versus SIT (\( p=0.07, d=0.60 \)) were detected. However, medium-sized effects were found between MICT and HIIT (\( d=0.56, 95\% \text{ CI } [-0.01, 1.12] \)) and between HIIT and SIT (\( d=0.60, 95\% \text{ CI } [0.08, 1.11] \)), suggesting that participants tended
to complete more sessions of MICT than HIIT, and more sessions of HIIT than SIT (see Table 3.2).

**Correlational analyses.** For MICT, the peak negative in-task FS was correlated with MICT enjoyment ($r=0.47, p<0.01$) and frequency of MICT behaviour ($r=0.40, p=0.02$), but not with preferences for MICT in the lab or during free time ($p>0.05$; see Table 3.3). Enjoyment of MICT was not correlated with preferences for MICT in the lab or during free time, or MICT behaviour ($p>0.05$; see Table 3.3).

For HIIT, the peak negative FS was correlated with HIIT enjoyment ($r=0.45, p<0.01$) and preferences for HIIT in the lab ($r=-0.41, p=0.01$), but not preferences for HIIT during free time or frequency of HIIT behaviour ($p>0.05$; see Table 3.3). Enjoyment of HIIT was correlated with preferences for HIIT in the lab ($r=-0.61, p<0.01$) and during free time ($r=-0.46, p<0.01$), but not with HIIT behaviour ($p=0.28$; see Table 3.3).

For SIT, the peak negative FS was correlated with SIT enjoyment ($r=0.32, p=0.04$) and preferences for SIT in the lab ($r=-0.47, p<0.01$) and during free time ($r=-0.38, p=0.02$), but not with frequency of SIT behaviour ($p=0.36$; see Table 3.3). Enjoyment of SIT was correlated with preferences for SIT in the lab ($r=-0.50, p<0.01$) and during free time ($r=-0.34, p=0.04$), but not with SIT behaviour ($p=0.19$; see Table 3.3).

Overall, smaller declines in in-task FS were associated with greater enjoyment of MICT, HIIT, and SIT, respectively. Further, smaller declines in in-task FS were associated with greater preferences for HIIT and SIT, but not for MICT. Smaller declines in in-task FS were associated with more sessions of MICT completed over 4 weeks, but not with HIIT or SIT sessions. Greater enjoyment of HIIT and SIT were associated with greater preferences for HIIT and SIT, respectively, but enjoyment of MICT did not predict preferences for
MICT. Exercise enjoyment did not predict exercise behaviour for any of the three exercise types.

### 3.3.2 Qualitative Results

The thematic analysis of the interview data was organized into five overarching themes: (1) previous thoughts and beliefs about exercise, (2) lab-based exercise experiences, (3) free time exercise experiences, (4) comparing and contrasting exercise experiences, and (5) changes to thoughts and beliefs about exercise. In addition, multiple sub-themes were identified and discussed within each theme (sub-themes are labelled in italics within each theme). While the data have been organized this way for ease of presentation, there is certainly overlap in the information presented within the five themes and their respective sub-themes. This overlap will be addressed in the discussion.

**Theme 1: Previous Thoughts & Beliefs About Exercise**

Participants’ initial thoughts and beliefs about various forms of exercise were framed by their previous experiences and knowledge gained from a variety of sources. As a result, there was a wide range of beliefs about MICT, HIIT and SIT. While thoughts about these forms of exercise varied, one sub-theme was *Exercise Familiarity*: the extent to which individuals were familiar with the various exercise protocols. Many participants felt they were most familiar with traditional, continuous forms of exercise like MICT. When asked about MICT, one female participant stated:

I think [MICT] is the type of exercise that, well at least for me, that I am most familiar with. I think whether it is media or friends or family, you kind of think of an hour of fitness or exercise as the standard … I guess it’s kind of ingrained in my head
that more than 30 minutes is probably the standard amount of time you want to be keeping up some kind of moderate exercise. (F16)

While most participants were familiar with MICT, many were also unfamiliar with HIIT or SIT. In particular, participants expressed a lack of awareness of exactly what HIIT or SIT were, or how to do them. One participant discussed her general thoughts about HIIT: “I don’t know what exactly that does to my body or what it’s going to be … So I guess the unfamiliarity of it is striking me the most about [HIIT]. I guess I kind of reserve it for like people who know what they are doing in terms of exercise” (F16). When asked about SIT, another participant replied: “Sounds brutal. Sounds very hard I’ve never tried it, I’ve never really heard of it either” (F1). Participants also expressed their uncertainty of the benefits of HIIT or SIT in comparison to MICT:

I would say I don’t know enough information to differentiate why there would be more benefits in doing high intensity exercise over moderate intensity exercise and so I think I would prefer doing moderate exercise over a greater period of time than a short period of high intensity exercise. (F2)

*Popularity of HIIT and SIT*: many participants acknowledged the perceived popularity of interval exercise based on what they had seen or heard. One participant highlighted this by saying:

It seems like it’s the thing now that a lot of people are going towards, like fitness trainers and even just everyday people. You hear Crossfit and stuff like that, right. So it seems like it’s become more and more popular and maybe that’s because the science is catching up and realizing that it’s a good benefit. (M3)
Another participant discussed what she had heard about interval exercise from her friends: “I've also heard of a lot of YouTube videos now have these minute-long exercises and you know, Insanity or whatever it’s called … they do all these minute exercises and cool downs and I know a lot of friends think that that’s the best way of getting fit and getting healthy and losing weight, so I hear a lot about that” (F4).

*Intimidation of HIIT and SIT:* other participants seemed to be intimidated by the high-intensity nature of HIIT or SIT. When asked about her thoughts about SIT exercise, one participant suggested: “[SIT] sounds very complicated and I don’t think I've ever done anything like that before. Sounds a little difficult to be honest” (F15). Another participant was more blunt in his response about SIT: “I’d probably hate [SIT]. Just because it’s exerting yourself all at once, which is not something I like to do” (M1). In a similar vein, many participants perceived interval exercise to be more appropriate for athletes or people undergoing high-level training. As one male participant stated: “A lot of athletes use [HIIT]. Body builders, stuff like that … I guess it’s more known to be people who are at that level of training” (M2).

*Time-Efficiency of HIIT and SIT:* finally, some participants felt the time-efficiency of interval exercise was appealing and for that reason, it was something they would be open to trying. For instance, when one participant was asked about HIIT she said: “It’s a very short type of exercise so that’s very appealing because you could just do a quick 20 minute exercise” (F4). The same participant also expressed her interest in SIT: “I guess I think it sounds very appealing and very tempting to do because it takes less time and it’s still working out your body in the same way that low intensity exercise would be for a longer duration of time” (F4).
Theme 2: Lab-Based Exercise Experiences

Participants perceived a wide range of positive (e.g., energizing, motivating, invigorating) and negative (e.g., fatiguing, sore muscles, demotivating) physical and psychological experiences during each of the MICT, HIIT, and SIT trials. Such positive and negative experiences were not exclusive to one type of exercise. MICT Boredom and Amotivation: participants tended to express feelings of boredom and a lack of motivation to persist during the MICT trial. For example, one participant described her experiences during the MICT trial:

And then during it, I felt mostly bored. I’d say physically I wasn’t exerting myself at the maximum compared to the other exercises. So it was a really long time to do the exercise and I was just kind of like ‘oh when is this going to end’, this is really not enjoyable (F2).

Another sub-theme was Exercise Engagement, the extent to which participants felt engaged during the various exercise trials. Some participants expressed their appreciation for not having to devote all of their attention towards the exercise during their MICT trial: “It’s less focusing on the actual exercise and I can let my mind wander … it’s easier to complete in that sense” (M5). On the other hand, many participants felt they were particularly focused and engaged during the HIIT trials: “I like [HIIT] the most because I felt most involved in it physically and mentally – there was no time to get distracted” (F17). This idea is consistent with a participant’s suggestion that he felt he was most engaged, and got the most out of, his HIIT trial: “The high intensity exercise I liked the best. I felt like I got the most out of it and it was the most energizing actually. I felt pretty good throughout it, I didn’t feel really tired or really disengaged. I felt pretty engaged throughout it” (M6). Another participant stated
about HIIT: “I feel that I’m having a good workout and I’m actually sweating and getting the benefits from it” (F1).

**Fatigue vs. Rest During HIIT and SIT:** participants tended to express feelings of exhaustion or soreness more frequently during HIIT and SIT trials than compared to MICT. For instance, when describing her experiences during SIT, one participant said: “Physically, it was exhausting … I felt like I was over-exerting myself” (F4). Another participant echoed these comments: “During [SIT] I felt exhausted, my muscles were hurting, even on my butt” (F18). Despite feelings of exhaustion during SIT, some participants believed the rest periods were very helpful:

I found it was exhausting – the sprint intervals of course, but … I liked that we had the breaks in between and I found it was more feasible to do because there were longer breaks and it was a shorter period of time that you were exercising. (F4)

Similar comments were also made about HIIT: “I like how I could stop for a whole minute and just pace myself and then do another set again” (F18). Interestingly, several participants shared their mindset when battling fatigue during HIIT and SIT. One participant expressed her experience during HIIT: “During, I was physically tired and then psychologically I was going between telling myself to give up and to keep going.” (F5).

Another sub-theme was *Sense of Accomplishment During HIIT and SIT*, where participants expressed feelings of accomplishment during or following the interval exercise protocols. For example, one participant expressed feeling good about completing his SIT trial:

I felt like after the first [sprint] I could actually, you know, go through the entire thing and psychologically I felt good too because I was physically fine … I was sort of
reassured that I could complete this exercise. After the third [sprint] I felt really good. Although I was tired, I felt really good psychologically because I got through it.

(M10)

Similarly, a different participant also expressed a sense of achievement after completing SIT: “Being able to give everything you have or to push yourself to do that for even short amounts of time, that’s still rewarding in itself … So I think that was probably why I found [SIT] the most interesting and enjoyable” (F14).

**Theme 3: Free Time Exercise Experiences**

For many participants, it was apparent that their experiences completing exercise in a controlled, lab-based setting differed from their experiences completing exercise on their own, outside of the lab. This variability is reflective of the fact that there are a multitude of additional factors to consider when attempting to exercise outside of a tightly controlled lab environment. For example, the **Versatility of MICT** was apparent as participants frequently suggested that having access to exercise equipment, a gym, or a quiet place to complete HIIT or SIT was particularly important, whereas MICT was easier to do outside. One participant explained:

The way that my life is structured, I enjoy [MICT] – just running because it’s easiest to do. I don’t have to go to a gym or find like a track or a long piece or stretch of road that I can do hard running on. (M3)

The same participant elaborated by saying: “[MICT] is versatile, you can do it outside, inside. It’s easy to do, it’s quick – if you have an hour, you know you can go do it. You can enjoy the weather outside, so I enjoy doing it” (M3). On the contrary, another participant expressed her lack of motivation to participate in MICT on her own: “To be
honest, it’s hard to find an incentive to do it. I would like to do more of it because I do have
the time for that in my schedule … but I can’t say it’s easy to find the motivation” (F2).
However, several participants mentioned that when completing MICT outside of the lab they
would have the ability to watch TV or listen to music, which they were not permitted to do in
the lab. When speaking about MICT, one participant mentioned: “I think in my own time I
could probably listen to music or something and that would make it a little bit more bearable”
(F10). Another participant explained that she would be more likely to do MICT on her own
for the same reason: “If I had music or was running outside, I think it’d be better and I’d
actually do it more” (F3).

*Difficulty Tracking or Timing HIIT and SIT:* a prominent concern that participants
had when attempting to engage in HIIT or SIT on their own was that it required more effort
to keep track of, and to time their workouts. One participant expressed this challenge when
attempting HIIT on her own:

I think it is easier when someone’s giving you specific instructions. I am good at
following instructions, so I think in a controlled setting or maybe if I was with a
partner, I could do that. I think on my own I can’t keep track of it, so I have a lot more
difficulty. And in this case, I was with my dogs so it would have been hard for them
to stop and start all of the time. (F2)

*HIIT and SIT Exercise Modalities:* many participants took it upon themselves to try
HIIT or SIT at home using different modalities than what was used in the lab. For example,
one participant discussed completing HIIT in the form of stairclimbing at home: “And
[HIIT], I guess I decided it was easy to do at home – I could do stair climbing for a minute at
a time and that’s what I wanted to try doing to see how I’d like that” (F4). Another participant described his interest in completing HIIT in the form of body weight intervals:

I’m going to try to do more body weight [HIIT] because I found that can be good in the mornings. Get up and try to throw in some intervals of push-ups and sit-ups, and I actually got a door for chin-ups and pull-ups which is really good, so – yeah I got to try to do more of that and, yeah I don’t know, I like it. (M3)

Challenges Completing HIIT and SIT: some participants expressed the challenges of completing HIIT or SIT on their own in less comfortable settings and without full knowledge about how to do them on their own. One participant felt SIT was the hardest protocol for him to complete on his own:

It’s kind of awkward if you’re sprinting on the treadmill at the gym, you know if you step on the side or something you’re going to go flying. And you can’t really do it on the pavement when you’re running, you’ve got to find a track or a really good place to run … you really have to want to do it because you’re going to be ‘that guy’ at the gym who’s just going as hard as he can. So you really have to want to do it and you have to know what you’re doing. (M3)

Theme 4: Comparing & Contrasting Exercise Experiences

When participants were given the opportunity to reflect upon their experiences with engaging in MICT, HIIT and SIT in the lab or on their own, a multitude of thoughts were expressed in their interviews. Participants had mixed preferences for the three protocols for a variety of different reasons. Preference for MICT: although preferences for MICT, HIIT, and SIT were similar based on experiences in the lab, many participants expressed an overall tendency to engage in MICT over HIIT or SIT on their own. This seemed to be, in large part,
due to the fact that participants felt MICT was less complicated than HIIT or SIT to complete on their own, and they were most familiar with and accustomed to MICT to begin with:

It’s familiar and it’s easy – you throw on your shoes go for a run. That’s part of it – so familiarity, the easiness of it. But also I find that you don’t have to think about it – like if you have half an hour or 40 minutes, you don’t have to think about getting your watch and structuring it exactly. Whereas with the [HIIT] or the [SIT], you got to kind of structure it, you got to plan out your workout and so there’s that component. (M3)

On the contrary, many participants engaged in HIIT on their own and indicated a Preference for HIIT over MICT or SIT. A contributing factor was that participants perceived HIIT to sit in the middle of the trade-off between exercise intensity and duration:

I liked [HIIT] because I liked how I didn’t like have to exert myself either completely for a short amount or barely exert myself throughout a long period of time, I liked having it kind of in between where I could exert myself for a decent amount of time, then have a break and then be able to do it continuously for a certain period of time. I found it – I just found it probably the most beneficial and the most refreshing in a sense. (M6)

Others felt HIIT was appealing because it was less boring and provided them with sense of accomplishment: “It’s just enough to make me sweat so I feel like I accomplished something. And at the same time, I wasn’t really bored or my mind wasn’t really wandering anywhere else like [MICT]. And [MICT] kind of gets boring because it’s the same consistency over and over” (F12). One participant acknowledged that although they did not find HIIT to be pleasurable, they still preferred it because of its intermittent nature: “You can
handle doing like one minute of a lot of exercise and then being like, ‘okay I am going to have a break’ and then do another minute. It’s not very pleasurable, but it’s not as boring I would say” (F2).

Preference for SIT: when it came to SIT, participants seemed to be very intrigued with its time-efficiency, despite the “all-out” nature of the sprint bouts. One participant spoke about this when discussing SIT:

Time-wise it just looks less daunting than committing yourself to, I guess like, an hour if you think about getting ready for exercise, stepping out of the house – that kind of stuff. So I guess if you compare maximum 15 minutes to an hour plus shower time and all that, then it seems a lot more feasible in terms of schedule wise … can you fit in ten minutes per day? It seems like an obvious yes for the most part versus an hour, so I think that in my free time if I had to commit to it regularly, then time-wise [SIT] definitely looks the most appealing. (F16)

Overall, it was not surprising that there were a number of different reasons why participants may have gravitated to one form of exercise over another. However, this does not mean that participants chose to engage in one form and to forgo the others. Combinations of MICT, HIIT and SIT: many participants reported engaging in combinations of more than one form of MICT, HIIT, or SIT on their own. One example comes from a participant who predominantly engaged in MICT and HIIT on her own time. She explained that when she felt low on time because she was busy with school or studying, she would opt for completing HIIT over MICT:

School was a big one because if I had something to study for I'd be like ‘okay, I can’t do [MICT] obviously’ so I'd have to go with [HIIT]. So that was another reason why I
did [HIIT] more, so I was able to go to the gym and go to school as well since it only took 20 minutes or around that time. (F8)

**Theme 5: Changes to Thoughts & Beliefs About Exercise**

Over the course of the study, many participants changed their thoughts and beliefs towards MICT, HIIT and SIT at different time points and for different reasons. *Changes from Pre- to Post-Study:* many participants entered the study with a limited understanding of what HIIT or SIT were, but expressed a better understanding of the exercise after completing the study and trying HIIT and SIT for their first time. When asked about his thoughts about HIIT at visit 1, one participant responded by saying: “Not the biggest fan of high intensity interval exercises” (M11). At visit 5, that same participant shared his new thoughts about HIIT:

> I didn’t really know what it was going in, I sort of had an understanding that it was going to be on and off, you know doing something intensely, and then break and then you know rinse and repeat but … you know now that I've actually experienced [HIIT], it’s much more clear to me what it is now and something I would consider doing more on my own time. (M11)

Similarly, when another participant was asked about SIT at visit 1, she said: “That one I think would be the most difficult one” (F11). However, when discussing SIT at visit 5 she stated:

> I really like that one. I thought it was a good alternative, I didn’t know about the whole interval thing beforehand so I really like that and it wasn’t too much for me. I feel like I was still working out and doing a good job even though I wasn’t really tired and didn’t feel as discouraged doing it. So I really like that one. (F11)
Another participant echoed a similar change in his opinions about SIT: “I didn’t really have an opinion going into this study but after coming out of the study, [SIT] wasn’t that bad, it was a lot better than I thought it’d be. I thought it would be really painful and agonizing but it wasn’t that bad” (M5).

Changes from In-Lab to Free Time: participants also experienced changes in their thoughts about the exercise they completed in the lab after completing exercise on their own. For example, based on her experiences in the lab, one participant expressed a preference for completing SIT on her own time. However, she had a change of mind when discussing HIIT and SIT at the end of the study:

I always thought [interval exercise] – it’s like it’s high intensity but it’s over within a few minutes. So that’s why I kind of thought I’d like it more, but after actually doing those things, because I never did them before, I prefer the moderate one just because [interval exercise] didn’t make me feel that great, so I prefer feeling good while I'm doing the exercise and after. Like the [interval exercise] made me feel better shortly after I finished the exercise but not so much during, so I prefer just enjoying it while it’s happening. (F6)

Another example of changes in thoughts about lab-based experiences occurring after completing exercise on their own comes from a participant who, following her HIIT trial completed in the lab, stated: “I don’t want to do it. I wouldn’t do it again” (F15). She subsequently completed HIIT during her own free time and expressed a change in her belief:

I actually didn’t mind it … when I was doing [HIIT] in the lab, it was not fun – maybe it was because it was biking, and I’m not used to biking that often. I remember
in the beginning I wasn’t too sure what it was either, so now I know what it is and it is not that bad. So, I like it. (F15)

3.4 Discussion

The primary finding from the current study was that despite experiencing elevated RPE and HR as well as negative affective responses during HIIT and SIT, inactive individuals still reported similar levels of post-exercise enjoyment and preferences for MICT, HIIT, and SIT. A second key finding was that smaller declines in MICT in-task affect were associated with more MICT behaviour over 4 weeks, but in-task affect and subsequent behaviour were not correlated for HIIT or SIT. A third key finding was that smaller declines in in-task affect and greater post-exercise enjoyment were associated with greater preferences for HIIT and SIT, but not for MICT, respectively. To our knowledge, this is the first study to investigate psychological responses to MICT, HIIT, and a practical 3 x 20-s SIT protocol and whether these responses predict subsequent exercise behaviour over a follow-up period.

Furthermore, the qualitative findings offer novel insights into people’s experiences of MICT, HIIT, and SIT performed inside and outside of a lab setting, and how these experiences may have shaped their beliefs about, and intentions to engage in, these types of exercise in the future. The following discussion integrates the quantitative and qualitative findings in order to provide a deeper understanding of how inactive individuals respond psychologically to MICT, HIIT, and SIT, and why they may or may not choose to engage in these forms of exercise (Bryman, 2006).

3.4.1 Affective Responses

Consistent with the hypotheses and previous research evidence (Stork et al., 2017), affective responses were more negative in-task for HIIT and SIT in comparison to MICT.
Notably, peak negative affect during both HIIT ($M=-1.47$) and SIT ($M=-0.80$) dropped into negative valence, while MICT responses remained in positive valence ($M=0.27$). During MICT, participants experienced a gradual decline in affect over time (see Figure 3.3). During HIIT and SIT, affect became more negative during the high-intensity work bouts and “rebounded” more positively during rest periods (relative to the work bouts; see Figure 3.3). Although affect did “rebound” during the rest periods of HIIT and SIT, these “rebounds” tended to become less positive over repeated bouts. For instance, affective responses during rest periods 8 and 9 of HIIT both remained in the negative valence (see Figure 3.3). These acute changes in affect observed in-task support the predictions of the dual-mode theory (Ekkekakis, 2003), whereby affect is proposed to become more negative as exercise intensity increases. Further, a rebound to more positive affect was observed following all three exercise protocols (see Figure 3.3), which also aligns with the dual-mode theory (Ekkekakis, 2003) and existing evidence (Stork et al., 2017).

There were no significant between-condition differences in affective responses pre, during, or 10- or 20-min following HIIT and SIT. These results provide the first evidence that, among inactive adults, affective responses to a 3 x 20-s SIT protocol are no more negative than affective responses to a 10 x 1-min HIIT protocol. It is possible that the brevity (20s) and frequency (3 bouts) of the “all-out” SIT intervals and the short total exercise duration (10 min) render this particular SIT protocol more tolerable than traditional forms of SIT (e.g., 4 x 30-s), despite the “all-out” work interval intensity. This interpretation aligns with exercise physiologists’ rationale for developing 10-20s sprint protocols (instead of 30s sprint protocols) in order to “make the training sessions more time-efficient, less strenuous and more applicable to the largely sedentary general population” (Metcalfe et al., 2012). This
interpretation also aligns with our qualitative findings. In their interviews, many participants expressed the time-saving appeal of SIT and that they felt SIT was less arduous than they initially anticipated.

3.4.2 Exercise Enjoyment

Consistent with our hypotheses, there were no significant differences in enjoyment between HIIT and MICT. However, contrary to hypotheses, enjoyment of SIT was equal to that of HIIT and MICT. Overall, these findings align with the majority of current evidence showing that exercise enjoyment is similar or greater following HIIT or SIT compared to MICT (Stork et al., 2017). One explanation for these findings may be that interval exercise is different from, and more challenging and stimulating than, traditional forms of exercise; challenge and stimulation are factors that may influence exercise enjoyment (Bartlett et al., 2011; Raedeke, 2007). In support of this notion, the qualitative data in this study revealed that many participants felt particularly engaged, focused, and energized during their HIIT trials. In addition, the brevity of the work intervals, the periods of rest between each interval, and the reduced total time commitment, may make interval exercise a less monotonous, and more appealing and enjoyable form of exercise than continuous exercise (e.g., Jung et al., 2014; Stork et al., 2017). Indeed, although participants expressed feelings of exhaustion or displeasure during HIIT or SIT in this study, many participants believed that the inclusion of rest periods made the exercise more bearable and less boring. These factors may, in part, explain why enjoyment of HIIT and SIT was not significantly different from MICT, despite participants reporting elevated RPE and negative affective responses during HIIT and SIT.
3.4.3 Exercise Preferences & Behaviour

Contrary to the hypotheses, all three exercise protocols were preferred equally. This finding is consistent with results from two previous studies showing non-significant differences in preferences between HIIT and MICT (Jung et al., 2014; Little et al., 2014). Both studies were conducted among inactive male and female adults, but did not include comparison with a SIT protocol. To our knowledge, this is the first study to compare preferences between MICT, HIIT, and SIT among inactive adults. It has been suggested that the intermittent nature and relative intensities of the work bouts may make interval exercise more adaptable and tolerable than some people may believe (Jung et al., 2014; Stork et al., 2017), and this may explain why studies tend to report equal/greater enjoyment and preferences for HIIT and SIT in comparison to MICT. Findings from the participant interviews in the current study support this interpretation. Interestingly, while in-task affective responses were most negative during HIIT in the current study, HIIT tended to be preferred (in lab) in comparison to MICT and SIT.

It should be noted that, although not statistically significant, participants’ preferences to complete the exercise during their own free time tended to favor MICT over HIIT and SIT. This is also in line with the frequency of exercise behaviour reported, whereby participants tended to complete more sessions of MICT than HIIT and SIT over the 4-week follow-up. These findings may be due to participants having previous experience with MICT (60% of participants reported that they had previously engaged in MICT prior to participating in the study), while no participants reporting previously engaging in HIIT or SIT. This was also reflected in the participant interviews; participants expressed familiarity and comfort with MICT and unfamiliarity with HIIT and SIT. Extensive research shows that past physical
activity behaviour is the strongest predictor of future physical activity behaviour (e.g., McEachan, Conner, Taylor, & Lawton, 2011), which would suggest that participants were more likely to engage in MICT on their own because they had engaged in it previously.

In addition, because no participants had experience with the HIIT and SIT protocols, they may have felt less capable of completing HIIT or SIT on their own time because they were less comfortable with, and less aware of how to complete, HIIT or SIT outside of the lab. This point is illustrated by the fact that many participants expressed a lack of knowledge about how to do HIIT or SIT on their own and discomfort when attempting to try HIIT or SIT in less controlled exercise settings, such as the gym. Further, the HIIT and SIT protocols were completed in the lab using specialized exercise equipment and with the direction from an experimenter, which are exercise opportunities they likely would not have on their own. For example, a major concern expressed by participants when trying HIIT or SIT on their own was that it was difficult to keep track of, and to time their workouts, without help from someone else. Likewise, not having access to a gym or exercise equipment were also perceived to be major barriers to participating in HIIT or SIT. Moreover, participants felt MICT was more versatile and easier to track on their own and complete outside.

According to Michie’s COM-B system of behaviour change (Michie, van Stralen, & West, 2011), perceptions of personal capability, opportunity, and motivation are precursors to engaging in a particular behaviour. Despite apparent motivation to engage in HIIT and SIT (as indicated by the preferences measures), study participants may have lacked the perceived capability and opportunity to engage in HIIT or SIT during their own free time for the reasons mentioned above. Inactive individuals may require continued supervised opportunities and experiences of completing HIIT or SIT, or further direction on how to do
it, before they feel capable and motivated to consistently engage in HIIT or SIT on their own. Nevertheless, it is encouraging that 79% of participants completed at least one session of HIIT and 54% completed at least one session of SIT on their own time. In addition, several participants completed HIIT and SIT at home and/or used different modalities from what they used in the lab such as body weight exercises or stairclimbing.

Together, the exercise preferences, behavioural, and qualitative data from this study highlight the need for future research to a) investigate what role prior exercise experiences may play in determining people’s current preferences for various forms of interval or continuous exercise and b) evaluate specific factors (e.g., perceived capability, barriers and facilitators) that impact people’s ability to participate in interval exercise in real-world settings and over the long term (see also Stork et al., 2017). Such research has the potential to guide the development of more effective real-world applications of interval exercise and further our understanding of how best to provide people with opportunities to engage in both continuous and interval exercise.

### 3.4.4 Correlational Findings

Consistent with the hypotheses and previous evidence (Greene et al., 2017), smaller declines in in-task affect were associated with greater post-exercise enjoyment for each type of exercise. Further, in-task affect during MICT predicted MICT behaviour over the next 4 weeks, which also aligns with the hypotheses and previous research (Rhodes & Kates, 2015). However, contrary to the hypotheses, in-task affect during HIIT or SIT did not predict subsequent HIIT or SIT behaviour (respectively) over the 4-week follow-up. These results may suggest that affective responses to interval exercise protocols do not predict future interval exercise behaviour. Alternatively, the fluctuations in affect during the bouts and rest
periods of interval exercise may need to be accounted for when using affect to predict future interval exercise behaviour. The fluctuations in affect experienced in-task during HIIT and SIT may have complicated how affect was able to predict behaviour because it did not follow the same steady decline over time that was observed during MICT.

Another consideration that should not be overlooked is how participants reflected upon and cognitively appraised their exercise experiences. Although all participants may have experienced the physical demands of the work periods and reduced pleasure during the HIIT or SIT trials, not all participants reflected upon these experiences the same way. Some participants expressed an appreciation for the rest periods and/or appraised their exercise sessions as an achievement, and these may have been incentives to try HIIT or SIT again on their own. Others expressed an aversion to the high-intensity work intervals and appraised the exercise as overly strenuous, and these may have been deterrents to future participation. It is certainly possible that participants’ conflicting reflections and opinions about HIIT and SIT may have contributed to muddying the relationship between affect and behaviour. In addition, many participants changed their thoughts and beliefs towards MICT, HIIT and SIT at various time points over the course of the study. Quantitative measurements of affect that occurred during the lab-based exercise trials and behaviour reported in the follow-up period likely would not have captured such nuanced changes. Cognitions that underpin exercise intentions and behaviour would have continued to evolve when participants left the lab setting, so using lab-based affective responses alone to predict exercise behaviour may have been difficult. Ultimately, the exercise affect-behaviour relationship may not be so simple, especially when it comes to interval exercise. Given the lack of research testing the predictive relationship between affect and behaviour for interval exercise, future research is
encouraged to investigate if these findings hold true for various participant samples, forms of interval exercise, and durations of behaviour measurement.

### 3.4.5 Strengths and Limitations: Quantitative Component

The quantitative component of this study has several strengths. Based on a scoping review of the psychological responses to interval exercise (Stork et al., 2017), the following steps were taken to minimize potential confounders: the gender of experimenters present during each exercise trial was controlled (1 male, 1 female); communication with participants was scripted for all visits; participants were familiarized with and reminded about the differences between the scale measures throughout the study; diurnal variation was controlled for; exercise trials were separated by 7 days; and the lab setup, procedures, and environment were carefully standardized. Further, both RPE and HR data were collected as manipulation checks to ensure participants were exercising at the desired exercise intensities and VO₂max was measured in order to supplement self-reported measures of physical activity. Finally, each exercise protocol administered in this study was carefully selected based on previous research showing similar physical benefits over several weeks of training.

Some potential limitations of the quantitative methods should be mentioned. Reports of MICT, HIIT, and SIT behaviour were collected over the short-term (4 weeks) and may have been susceptible to self-report biases (e.g., Sallis & Saelens, 2000). For example, social desirability bias can lead to over-reporting of exercise levels and exercise logs are limited by the extent to which participants follow instructions, the rate of responses being made, and by participants’ ability to recall their exercise behaviour (Sallie & Saelens, 2010). As a result, this may have influenced the affect-behaviour relationships reported. Notwithstanding, this study was the first to investigate the affect-behaviour relationship using HIIT and SIT, and
future studies evaluating exercise behaviour over the longer term and using objective measures (e.g., accelerometers) are encouraged.

For the current study, total exercise duration and energy expenditure were not controlled for between MICT, HIIT, and SIT. However, this decision was made in order to capture the trade-off between varying exercise intensity and duration and the potential time-saving appeal of HIIT and SIT in comparison to MICT (see also Stork et al., 2017). Although the results from the current study provide new and important findings about MICT, HIIT, and SIT, such findings need to be replicated in future studies. Finally, this was an acute study of MICT, HIIT, and SIT, so we cannot infer how several weeks of training using these exercise protocols may impact participants’ psychological responses and exercise preferences.

3.4.6 **Strengths and Limitations: Qualitative Component**

The strengths of the qualitative component of this study can be drawn upon using Tracy’s (2010) criteria. For example, the topic of the current study can be considered *worthy* because this is the first study to qualitatively analyze people’s experiences with MICT, HIIT, and SIT exercise, and is timely and relevant given the current controversy regarding interval exercise and the need for more research evidence in the area. Further, this study demonstrated *rich rigour* by following each step of the thematic analysis with care and thoroughness, engaging a critical friend with expertise in qualitative methods, using appropriate interviewing procedures conducted at multiple times throughout the protocol, and spending ample time familiarizing with the data, and analyzing a large sample of 30 participants. Finally, this study exemplified *meaningful coherence* by achieving the stated purpose, using methods that were consistent with the stated objectives and were sensitive to
change, and diligently interconnecting the study rationale, interpretations of the data, methods, and findings.

Limitations in the qualitative component should also be considered. Given that a concurrent embedded mixed-method design was used with a greater emphasis being placed on the quantitative component of the study, some elements of the quantitative procedures may have influenced the qualitative interviews. For example, all interviews conducted at lab visits 2-4 were conducted approximately 20 minutes following the exercise sessions in order to avoid contamination of the carefully controlled quantitative methods. As a result, thoughts that were fresh in participants’ minds during and immediately following the exercise trials may not have been captured during the interviews conducted 20 minutes later. However, it should be noted that the timing of interviews for each participant was standardized for consistency. Future studies could consider employing ecological momentary assessments where participants are prompted to discuss their exercise experiences during the actual exercise sessions (e.g., during rest periods of HIIT or SIT). Similarly, the controlled exercise procedures that participants experienced in the lab are not representative of how most people would experience HIIT and SIT for their first time. As a result, participants’ reflections about their first HIIT and SIT experiences were likely different from what they would have been in real-world settings (e.g., outside, at the gym) and this may influence the naturalistic generalizability of the qualitative findings (Smith & McGannon, 2017; Tracy, 2010).

3.5 Summary

Although interval exercise protocols such as HIIT or SIT have been advocated as time-efficient alternatives to traditional endurance exercise (i.e., MICT), our current understanding of how inactive individuals psychologically respond to such protocols is
limited (Stork et al., 2017). The present findings showed that, despite experiencing more negative affective responses during HIIT and SIT in comparison to MICT, inactive individuals still reported equal levels of post-exercise enjoyment and preferences for MICT, HIIT, and SIT. Importantly, this study shows that a SIT protocol consisting of 3 x 20-s “all-out” sprints can be completed, enjoyed, and even preferred over MICT or HIIT by some inactive individuals. Further, differences in the exercise affect-behaviour relationship were detected for interval and continuous exercise, such that affect experienced during exercise predicted 4-week exercise behaviour for MICT, but not for HIIT or SIT. Finally, the use of qualitative analysis provided a unique look into inactive people’s experiences of MICT, HIIT, and SIT, the meaning they attached to these experiences, and how such experiences may influence their decisions to engage in these forms of exercise again in the future.

Overall, these findings provide us with a new-found understanding of inactive people’s acute psychological responses to MICT, HIIT, and SIT, and what role such responses may play in predicting exercise preferences and future exercise behaviour. While research has previously shown that HIIT and SIT can elicit similar physical benefits as MICT over several weeks of training, this study provides new evidence that a single session of HIIT and SIT can be equally as enjoyable and preferable as MICT among inactive individuals. Moreover, there may be differences – or at least important caveats – in the exercise affect-behaviour relationship between interval and continuous exercise. This study prompts further consideration of how exercise is typically prescribed to the largely inactive population. For instance, it is possible that lab-based testing of people performing acute interval and continuous exercise protocols may be used to help determine individualized exercise programs that are most conducive to exercise enjoyment and adherence. Similar to evidence
that people have varied physiological responses to MICT versus SIT (Bonafiglia et al., 2016),
this study suggests that people also have varied *psychological* responses to MICT, HIIT, and
SIT. When it comes to exercise prescription, one size does not fit all; health care and exercise
practitioners should provide people with opportunities to engage in and try different forms of
continuous and interval exercise as a means of promoting physical activity and improving
public health.
Table 3.1. Participant characteristics.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Overall N=30</th>
<th>Women n = 18</th>
<th>Men n = 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>21.23 ± 3.81</td>
<td>21.06 ± 3.57</td>
<td>21.50 ± 4.30</td>
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<tr>
<td>Body mass (kg)</td>
<td>62.88 ± 11.20</td>
<td>57.85 ± 8.53</td>
<td>70.43 ± 10.71</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>166.88 ± 7.54</td>
<td>161.94 ± 5.09</td>
<td>174.29 ± 3.19</td>
</tr>
<tr>
<td>BMI (kg·m⁻²)</td>
<td>22.47 ± 3.02</td>
<td>22.04 ± 2.96</td>
<td>23.13 ± 3.10</td>
</tr>
<tr>
<td>HRmax (bpm)</td>
<td>183.90 ± 9.87</td>
<td>185.94 ± 7.70</td>
<td>180.83 ± 12.16</td>
</tr>
<tr>
<td>Wmax (watts)</td>
<td>195.70 ± 38.10</td>
<td>174.33 ± 20.46</td>
<td>227.75 ± 36.22</td>
</tr>
<tr>
<td>VO₂max (mL·kg⁻¹·min⁻¹)</td>
<td>31.3 ± 6.2</td>
<td>27.8 ± 3.3</td>
<td>36.5 ± 5.8</td>
</tr>
</tbody>
</table>

Note. Values are presented as mean ± SD. BMI = body mass index; HRmax = maximal heart rate; Wmax = maximal workload in watts; VO₂max = maximal oxygen uptake.
Table 3.2. Effect sizes and 95% confidence intervals for comparisons between MICT, HIIT, and SIT conditions.

<table>
<thead>
<tr>
<th>Measure</th>
<th>MICT – HIIT d [95% CI]</th>
<th>MICT – SIT d [95% CI]</th>
<th>HIIT – SIT d [95% CI]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RPE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work periods</td>
<td>1.64 [1.26, 2.01]**</td>
<td>2.28 [1.81, 2.74]**</td>
<td>0.80 [0.39, 1.21]**</td>
</tr>
<tr>
<td><strong>%HRmax</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work periods</td>
<td>2.32 [1.97, 2.67]**</td>
<td>1.10 [0.70, 1.49]**</td>
<td>1.06 [0.65, 1.46]**</td>
</tr>
<tr>
<td><strong>FS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-task</td>
<td>0.12 [-0.14, 0.37]</td>
<td>0.08 [-0.16, 0.32]</td>
<td>0.20 [-0.08, 0.48]</td>
</tr>
<tr>
<td>Peak negative in-task</td>
<td>0.82 [0.43, 1.22]**</td>
<td>0.52 [0.07, 0.97]</td>
<td>0.29 [-0.07, 0.65]</td>
</tr>
<tr>
<td>Change score</td>
<td>0.77 [0.37, 1.16]**</td>
<td>0.39 [-0.02, 0.80]</td>
<td>0.38 [0.03, 0.74]</td>
</tr>
<tr>
<td>0-min post-exercise</td>
<td>0.09 [-0.34, 0.52]</td>
<td>0.59 [0.17, 1.01]*</td>
<td>0.53 [0.05, 1.01]</td>
</tr>
<tr>
<td>10-min post-exercise</td>
<td>0.17 [-0.19, 0.52]</td>
<td>0.09 [-0.23, 0.41]</td>
<td>0.24 [-0.10, 0.59]</td>
</tr>
<tr>
<td>20-min post-exercise</td>
<td>0.02 [-0.25, 0.29]</td>
<td>0.11 [-0.13, 0.35]</td>
<td>0.09 [-0.18, 0.36]</td>
</tr>
<tr>
<td><strong>FAS</strong></td>
<td></td>
<td></td>
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<tr>
<td>Pre-task</td>
<td>0.13 [-0.29, 0.54]</td>
<td>0.06 [-0.22, 0.35]</td>
<td>0.08 [-0.34, 0.51]</td>
</tr>
<tr>
<td>Work periods</td>
<td>0.89 [0.47, 1.30]**</td>
<td>0.93 [0.46, 1.40]**</td>
<td>0.06 [-0.15, 0.28]</td>
</tr>
<tr>
<td>0-min post-exercise</td>
<td>0.25 [-0.21, 0.72]</td>
<td>0.22 [-0.11, 0.55]</td>
<td>0.03 [-0.37, 0.43]</td>
</tr>
<tr>
<td>10-min post-exercise</td>
<td>0.08 [-0.35, 0.50]</td>
<td>0.29 [-0.19, 0.76]</td>
<td>0.34 [-0.19, 0.86]</td>
</tr>
<tr>
<td>20-min post-exercise</td>
<td>0.12 [-0.42, 0.65]</td>
<td>0.30 [-0.15, 0.76]</td>
<td>0.19 [-0.20, 0.57]</td>
</tr>
<tr>
<td><strong>PACES</strong></td>
<td></td>
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<tr>
<td>0-min post-exercise</td>
<td>0.04 [-0.39, 0.46]</td>
<td>0.11 [-0.26, 0.47]</td>
<td>0.15 [-0.30, 0.60]</td>
</tr>
<tr>
<td><strong>Exercise Behavior</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>4-week follow-up</td>
<td>0.56 [-0.01, 1.12]</td>
<td>1.34 [0.84, 1.84]**</td>
<td>0.60 [0.08, 1.11]</td>
</tr>
</tbody>
</table>

Note. Values are presented as d [95% CI]. d = Cohen’s d effect size; 95% CI = 95% confidence interval of effect size; RPE = rating of perceived exertion; %HRmax = percentage of heart rate maximum; FS = feeling scale; FAS = felt arousal scale; PACES = Physical Activity Enjoyment Scale. N=30 for all variables, except for exercise behavior (N=28) due to missing data. *p < 0.05; **p < 0.01.
Table 3.3. Correlations between affect, enjoyment, preferences, and behaviour for MICT, HIIT and SIT.

<table>
<thead>
<tr>
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<th>1</th>
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<tbody>
<tr>
<td>MICT</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>1. MICT most negative affect (FS)</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td>0.27</td>
<td>1.76</td>
<td></td>
</tr>
<tr>
<td>2. MICT enjoyment (PACES)</td>
<td>0.47*</td>
<td>-</td>
<td></td>
<td></td>
<td>83.70</td>
<td>19.20</td>
<td></td>
</tr>
<tr>
<td>3. MICT preference (in lab)</td>
<td>0.00</td>
<td>-0.10</td>
<td>-</td>
<td></td>
<td>2.03</td>
<td>0.85</td>
<td></td>
</tr>
<tr>
<td>4. MICT preference (free time)</td>
<td>0.06</td>
<td>0.03</td>
<td>0.75*</td>
<td>-</td>
<td>1.73</td>
<td>0.83</td>
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<tr>
<td>5. MICT behavior (frequency)</td>
<td>0.40*</td>
<td>0.09</td>
<td>-0.15</td>
<td>-0.32</td>
<td>6.11</td>
<td>4.12</td>
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<tr>
<td>1. HIIT most negative affect (FS)</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td>-1.47</td>
<td>2.30</td>
<td></td>
</tr>
<tr>
<td>2. HIIT enjoyment (PACES)</td>
<td>0.45*</td>
<td>-</td>
<td></td>
<td></td>
<td>84.43</td>
<td>18.47</td>
<td></td>
</tr>
<tr>
<td>3. HIIT preference (in lab)</td>
<td>-0.41*</td>
<td>-0.61*</td>
<td>-</td>
<td></td>
<td>1.93</td>
<td>0.91</td>
<td></td>
</tr>
<tr>
<td>4. HIIT preference (free time)</td>
<td>-0.25</td>
<td>-0.46*</td>
<td>0.68**</td>
<td>-</td>
<td>2.10</td>
<td>0.80</td>
<td></td>
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<tr>
<td>5. HIIT behavior (frequency)</td>
<td>0.13</td>
<td>0.12</td>
<td>0.05</td>
<td>0.22</td>
<td>3.54</td>
<td>4.23</td>
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<tbody>
<tr>
<td>SIT</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. SIT most negative affect (FS)</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td>-0.80</td>
<td>2.20</td>
<td></td>
</tr>
<tr>
<td>2. SIT enjoyment (PACES)</td>
<td>0.32*</td>
<td>-</td>
<td></td>
<td></td>
<td>81.63</td>
<td>18.78</td>
<td></td>
</tr>
<tr>
<td>3. SIT preference (in lab)</td>
<td>-0.47*</td>
<td>-0.50*</td>
<td>-</td>
<td></td>
<td>2.03</td>
<td>0.72</td>
<td></td>
</tr>
<tr>
<td>4. SIT preference (free time)</td>
<td>-0.38*</td>
<td>-0.34*</td>
<td>0.67**</td>
<td>-</td>
<td>2.17</td>
<td>0.79</td>
<td></td>
</tr>
<tr>
<td>5. SIT behavior (frequency)</td>
<td>0.15</td>
<td>0.17</td>
<td>-0.02</td>
<td>-0.18</td>
<td>1.39</td>
<td>1.85</td>
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</tbody>
</table>

*Note.* Correlations between variables 3 and 4 are based on one-tailed Spearman’s correlation coefficients, while all other data are based on one-tailed Pearson’s correlation coefficients. For exercise preferences, a lower ranking value represents a higher preference. N=30 for all correlations, except for those involving variable 5 (N=28) due to missing data. *p < 0.05; **p < 0.01.
Figure 3.1. Individual power output data from one male participant for the MICT, HIIT, and SIT trials, graphed over time. Arrows represent the total exercise duration of each exercise trial.
Figure 3.2. Rating of Perceived Exertion responses (M±SE) during the MICT, HIIT, and SIT trials, plotted over time. W-Up, warm-up; CDown, cool-down; B1-B10, bouts 1-10; R1-R9, rest periods 1-9.
Figure 3.3. Feeling Scale responses (M±SE) before, during, and following the MICT, HIIT, and SIT trials, plotted over time. W-Up, warm-up; CDown, cool-down; B1-B10, bouts 1-10; R1-R9, rest periods 1-9; 0-Post, 0min post-exercise; 10-Post, 10min post-exercise; 20-Post, 20min post-exercise.
Figure 3.4. Felt Arousal Scale responses (M±SE) before, during, and following the MICT, HIIT, and SIT trials, plotted over time. W-Up, warm-up; CDown, cool-down; B1-B10, bouts 1-10; R1-R9, rest periods 1-9; 0-Post, 0min post-exercise; 10-Post, 10min post-exercise; 20-Post, 20min post-exercise.
Chapter 4: Let’s Go! Examining the psychological, psychophysical, and physiological effects of motivational music during sprint interval exercise

4.1 Background

Interval exercise is short-duration exercise that involves multiple brief, high-intensity efforts, separated by periods of rest or recovery (Gibala et al., 2014). Research shows that several weeks of interval exercise training can engender meaningful physical health benefits similar to those of traditional long-duration aerobic exercise among healthy, at-risk, and diseased populations (Batacan et al., 2017; Gibala et al., 2014; Weston et al., 2014). Despite convincing evidence of the numerous physical benefits elicited by interval exercise, one major drawback of this form of exercise is that people may find it unpleasant. Further, there is emerging evidence that insufficiently active individuals may experience affective responses to interval exercise that are more negative than those experienced by active individuals (Frazão et al., 2016). Taken together, there is concern that these factors may discourage continued interval exercise participation.

In light of the health benefits of interval exercise, but also its potential to be perceived as aversive, researchers have begun to investigate various strategies that can be used to enhance people’s psychological responses (e.g., affect, enjoyment, attitudes, self-efficacy) to interval exercise (e.g., Brown et al., 2015; Jones et al., 2017; Stork et al., 2015; Stork & Martin Ginis, 2017; Tritter et al., 2013). In particular, listening to music during exercise is a simple strategy that has been shown to improve affect and enjoyment, regulate arousal, and enhance exercise performance (e.g., Eliakim, Meckel, Nemet, & Eliakim, 2007; Hutchinson et al., 2011; Jones et al., 2017; Karageorghis & Priest, 2012a, 2012b; Miller, Swank, Manire, Robertson, & Wheeler, 2010; Stork et al., 2015; Yamamoto et al., 2003). Drawing from a
model of the study and application of music in exercise and sport (Karageorghis, 2016), it is possible that music can be used to create more positive exercise experiences when people engage in interval exercise, which may subsequently improve the likelihood of future interval exercise participation (see also Stork & Martin Ginis, 2017). However, there is limited research examining the effects of music during high-intensity exercise in general (Karageorghis & Priest, 2012a), and even fewer studies that have investigated the impact of music during high-intensity interval exercise in particular (Jones et al., 2017; Stork et al., 2015; Stork & Martin Ginis, 2017).

Previous research from our lab (Stork et al., 2015) has investigated the effects of self-selected music on the performance and enjoyment of a particularly intense form of interval exercise, referred to as sprint interval training (SIT). That protocol consisted of four 30-s “all-out” Wingate Anaerobic Test (WAnT; Bar-Or, 1987) sprints on a cycle ergometer, separated by a 4-min rest period (Stork et al., 2015). In that study, peak and mean power output were significantly higher over the course of the SIT protocol, and post-SIT enjoyment was significantly higher in the music condition compared to a no music control condition. Further, despite the “all-out” supramaximal nature of the exercise, music still had a positive influence on affective responses during SIT, whereby affect was consistently more positive in the music condition (Stork et al., 2015). It is important to note that the study implemented a particularly intense SIT protocol among active individuals. Little is known about the effects of music during SIT protocols that are more practical for insufficiently active individuals.

In recent years, exercise physiologists have adopted more practical SIT protocols that may be more appropriate for less active people (see Vollaard & Metcalfe, 2017). For example, one such protocol consists of 3 x 20-s “all-out” WAnT sprints, separated by a 2-
min recovery period and lasts for a total of 10min with the inclusion of a warm-up and cool-down (Gillen et al., 2014, 2016). Notably, this SIT protocol has been shown to elicit significant physiological benefits among previously inactive individuals following several weeks of training (Gillen et al., 2014, 2016). Given that this practical SIT protocol requires little total work time (60 seconds), is of short total duration (10 min), and can elicit important health benefits, it may be more appealing than traditional SIT protocols that require longer work periods and greater total exercise duration (see Stork, Gibala, & Martin Ginis, 2018; Vollaard & Metcalfe, 2017 for further discussion on traditional SIT compared to practical SIT). Further, if music can be used to improve people’s experiences during traditional SIT (Stork et al., 2015), music should also have positive effects on individuals’ experiences during a more practical SIT protocol.

Our previous study provided the first evidence of the psychological and physiological effects of listening to music during a SIT protocol (Stork et al., 2015); however, that study implemented self-selected music. Personalized music playlists were created for each participant based on songs they provided and enjoyed listening to while exercising. As a result, one limitation of that study was that there was large variability in the characteristics of the music played across participants (e.g., genre, tempo, epoch) and some participants may have selected songs with characteristics that may have not been appropriate for the high-intensity nature of the exercise. For example, while there is evidence that it is ideal to match high-intensity exercise to fast tempo (135-140 bpm) music (Karageorghis, 2016; Karageorghis et al., 2011), some participants in that study may have selected songs with slower tempos (e.g., 95-100bpm). Additionally, the motivational ratings of the music also varied between participants, indicating that the music intervention may have not been
sufficiently stimulating or motivating for all participants (Stork et al., 2015). This is an important consideration given that music’s impact on high-intensity exercise is believed to predominantly come from the motivational qualities of the music (Hutchinson & Karageorghis, 2013; Karageorghis, 2016). In order to have a more rigorous test of the effects of music and to maximize the efficacy of a music intervention, it is critical to control for musical characteristics and to apply music that is highly motivational.

In addition to controlling for characteristics of the musical stimulus, it is also important to control for the effects of simple auditory distraction (Chanda & Levitin, 2010). It has been suggested that during high-intensity exercise, the psychological effects of music are driven by the motivational qualities of the music as opposed to the ability for music to dissociate attention away from feelings of fatigue (Atkinson, Wilson, & Eubank, 2004; Hutchinson & Karageorghis, 2013). If this explanation is correct (i.e., that music functions to motivate rather than dissociate during SIT), then SIT performed in the presence of music should elicit greater psychological and physiological effects than when SIT is performed in the presence of a non-musical audio distraction. To test this possibility, the present study incorporated a non-music audio control (i.e., a non-musical audio podcast) condition in addition to a no audio control (i.e., silent) condition.

**Study Purpose and Hypotheses**

The purpose of this study was to investigate the psychological (i.e., affect, arousal, enjoyment), psychophysical (i.e., perceived exertion), and physiological (i.e., heart rate, power output) effects of researcher-selected motivational music during a practical SIT protocol performed by insufficiently active adults. Based on previous studies of the effects of music during traditional SIT (Stork et al., 2015) and a single WAnT performance
(Hutchinson et al., 2011), we hypothesized that the application of motivational music during practical SIT would lead to more positive affect, higher post-exercise enjoyment, and greater peak and mean power output when compared to an audio podcast and no audio control conditions. Further, we hypothesized that ratings of perceived exertion would not differ between the three conditions (Stork et al., 2015).

4.2 Methods

4.2.1 Study Design

This study used a repeated-measures crossover design, whereby each participant completed a total of three different exercise trials: motivational music, podcast (control), and no-audio (control). The exercise testing order was randomized, counterbalanced (using a 3 by 6 Williams Square design; Williams, 1946), and stratified by gender in blocks of 6. Each participant made a total of five visits to a lab located at Brunel University London, over the course of approximately 2-3 weeks.

4.2.2 Participants

Based on previous literature that found effect sizes ranging from 0.36 to 1.57 for differences in affect and enjoyment between music and no music interval exercise conditions (e.g., Jones et al., 2017; Stork et al., 2015), we powered for an effect of 0.96 based on the average of these effect sizes. Using a repeated measures analysis of variance (ANOVA) statistical test in G*Power 3 (Faul et al., 2007), a sample size of 18 was estimated to have 80% power to detect an effect of 0.96 (Cohen, 1992). In order to estimate conservatively and to achieve perfect stratification by gender, a sample of 24 participants was targeted. Twenty-seven insufficiently active men and women inexperienced with SIT were recruited and enrolled in the study. Participants were excluded from the study if they had any
contraindications to exercise based on the Physical Activity Readiness Questionnaire (PAR-Q). Participants were considered “insufficiently active” based on similar criteria used in a previous interval exercise study (Frazão et al., 2016) and as assessed by the International Physical Activity Questionnaire – Short Form (IPAQ-SF; median score = 260.00 MET-minutes/week, mean score = 312.50 MET-minutes/week of moderate and vigorous activity).

The University of British Columbia Clinical Research Ethics Board and the Brunel University London Research Ethics Committee approved the study protocol and participants were recruited through poster advertisements on campus. All participants provided written informed consent.

4.2.3 Psychological Measures

**Affect.** Hardy and Rejeski’s (1989) Feeling Scale (FS) was used to measure affective valence before, during and following the exercise trials. The FS is an 11-point bipolar, single-item scale that ranges from “Very Bad” (-5) to “Very Good” (+5) along a displeasure-pleasure continuum. The FS has been established as a reliable and valid measure of exercise-related affective states (Hardy & Rejeski, 1989).

**Arousal.** Svebak & Murgatroyd’s (1985) Felt Arousal Scale (FAS) was used to measure perceived activation (arousal) before, during and following the exercise trials. The FAS is a 6-point, single-item scale that ranges from “Low Arousal” (1) to “High Arousal” (6). It has been suggested that the concurrent use of FS and FAS strengthens the discriminant validity of these two scale measures (Ekkekakis, 2013).

**Exercise enjoyment.** Enjoyment of each exercise trial was measured immediately post-exercise using the Physical Activity Enjoyment Scale (PACES; Kendzierski & DeCarlo, 1991). The PACES was modified slightly so that the wording of each item was given in the
past tense (see also Stork et al., 2015; Stork et al., 2018). This scale has 11 negatively worded and 7 positively worded items that participants rated on a 7-point bipolar scale (from 1 to 7), indicating how they felt about the exercise they completed. The internal consistency was acceptable at each administration (Cronbach’s αs ≥ .95).

4.2.4 Psychophysical Measures

Perceived exertion. Borg’s CR-10 (Borg, 1998) rating of perceived exertion (RPE) scale was used, which has a scale increasing from “Nothing at all” (0) to “Absolute Maximum” (10). The RPE scale has been established as a valid and reliable measure of physical exertion during exercise (Borg, 1998).

4.2.5 Physiological Measures

Heart rate. Participants’ heart rate (HR) was continuously recorded every second throughout baseline fitness testing and each of the exercise trials using a HR monitor (Polar H7).

Power output. Peak and mean power output during cycling (in watts [W]) were measured using Velotron Wingate software (version 1.0.2; RacerMate).

4.2.6 Post-Experimental Measures

A post-experimental questionnaire was administered to measure the motivational nature of the auditory stimulus, and how much participants liked the auditory stimulus, during each exercise condition.

Liking. A single-item, rated on a 10-point scale ranging from “I did not like it at all” (0) to “I liked it very much” (10) was used to measure how much participants liked the auditory stimulus (or lack thereof) during each of the exercise conditions. For example, the liking item question for the music condition was as follows: “Please rate how much you liked
the music while it was played during that exercise session.” The item used for each condition can be found in Appendix C.1.

**Motivation.** A single-item, rated on a 10-point scale ranging from “It did not motivate me at all” (0) to “It motivated me very much” (10) was used to measure how much the auditory stimulus (or lack thereof) motivated participants during each of the exercise conditions. For example, the motivation item question for the music condition was as follows: “Please rate how much the music motivated you while it was played during that exercise session.” The item used for each condition can be found in Appendix C.1.

### 4.2.7 Protocol

**Familiarization 1 (visit 1).** Following confirmation of eligibility, participants provided their written informed consent. Eligible participants then performed the Astrand-Rhyming predictive maximal oxygen consumption (VO$_{2}$max) test (Astrand & Rhyming, 1954) on an electronically-braked cycle ergometer (Velotron, RacerMate, Seattle, WA, USA). Thereafter, participants completed a 2-min warm-up on the cycle ergometer followed by a single 20-s WAnT maximal sprint effort. After the warm-up, participants were given a 30-s and 20-s warning before the start of their “all-out” sprint and were instructed to start increasing their pedaling rate. Participants were given a verbal 10-s countdown until their “all-out” sprint began. During the 10 s leading up to the sprint, the ergometer resistance was dropped to 0W, and pedaling was unloaded for those 10 s. As soon at the countdown finished, participants were verbally prompted to begin the “all-out” sprint once they heard the word “Go!” Participants were asked to pedal as hard and as fast as they possibly could against a set resistance of 5% of their body mass (Gillen et al., 2014, 2016) for the entire 20-s “all-out” sprint. During the sprint, the experimenter provided the same verbal script to each
participant which consisted of non-motivational prompts of time remaining. This protocol was followed for each “all-out” sprint performed in all subsequent exercise trials. Participants were asked to report RPE, FS, and FAS at the very end of the 20-s sprint and subsequently filled out the PACES. The cycle ergometer was set up so participants were directly facing a wall on which the three measurement scales were posted. The scales were colour-coded to clearly differentiate between each and minimize common-method variance (see Stork et al., 2017; Stork et al., 2018).

**Familiarization 2 (visit 2).** Participants were asked to complete a SIT trial consisting of 3 x 20-s “all-out” sprints, separated by 2 min of low-intensity cycling at 50W (Gillen et al., 2016). The exercise trial lasted a total of 10 min, with the inclusion of a 2-min warm-up and 3-min cool-down at 50W. During the rest periods, participants were asked to pedal very lightly at 50W, without physically exerting themselves any more than a 1 (“very weak”) on the RPE scale. Participants were asked to remain seated on the bike at all times, including sprint bouts and rest periods. Following suit with visit 1, the “all-out” sprints were performed on the cycle ergometer with an applied resistance of 5% of body mass (Gillen et al., 2014, 2016). Participants were prompted to report RPE, FS, and FAS before, during (at end of/immediately following sprints 1, 2, and 3, and during the last ~35 s of recovery periods) and immediately following the final sprint, during the cool-down and at the end of the cool-down. Participants were prompted to report RPE, FS, and FAS with ~35 s left in the recovery periods (as opposed to the last 15s of the sprints) in order to allow time for verbal prompting leading into the 20-s all-out sprints and to ensure participants were performing the sprints at the desired “all out” intensity.

Reports of RPE, FS, and FAS were prompted immediately *following* the sprint bouts
for the SIT protocol due to logistical constraints with collecting scale responses during “all-out” cycling efforts. At these time points, participants were carefully instructed to report how they “felt during the final few seconds of the exercise.” At all other time-points (including rest periods), participants were instructed to indicate how they “feel right now.” Participants were reminded of these explicit instructions prior to each exercise trial. Participants were also prompted to report FS and FAS and filled out the PACES immediately following each exercise trial (following cool-down).

Experimental trials (visits 3-5). Before completing the exercise trials, participants had the exercise procedures explained to them in full and had the opportunity to ask questions. All three exercise trials performed at lab visits 3-5 were performed according to the exact same SIT and measurement protocols utilized for visit 2. The only difference was that participants were asked to remain in the laboratory for 10mins following the experimental trials and were prompted to report FS and FAS at 5- and 10-min post-exercise.

A portable stereo (JVC RV-NB20B) was placed on a small desk next to the cycle ergometer for all lab visits. For the music and podcast conditions, audio was played from the portable stereo at a volume of 72 dBA for the duration of the warmup, sprints, and recovery periods. No audio was played during the 3min cool-down as the effects of recuperative, post-exercise music was not part of this study’s research question. The audio was played on a stereo and not via headphones in order to enable verbal interaction between the participant and experimenter. In order to conceal the true purpose of the study, we did not specify that music or audio were to be played during any of the lab visits when the research team sent out recruitment materials or corresponded with participants. However, participants were aware that this study aimed to examine people’s psychological responses to SIT exercise.
Motivational music. Motivational music has been described as upbeat and stimulating music that “tends to have a fast tempo (>120 bpm) and a strong rhythm, and is proposed to enhance energy and induce bodily action” (Karageorghis, Terry, & Lane, 1999, p. 714). Participants were given the option to choose between three music genres that corresponded to three carefully edited songs (see Audio Selection and Editing below). As soon as participants were set up on the bike, the experimenter (MJS) offhandedly stated, “Oh, by the way, I’ve got my iPod with me today, so I will put on some music. What type of music do you prefer – pop, rock, or hip-hop?” If participants did not indicate a preference, the pop music song was selected. Podcast control. As soon as participants were set up on the bike, the experimenter (MJS) casually stated, “Oh, by the way, I’m going to be playing a podcast over the speakers today.” If participants queried why the podcast was being played, the experimenter simply explained that he wanted to have something playing in the background. No audio (silent) control. No music or audio of any type was played over the stereo throughout the SIT protocol.

Each exercise trial was scheduled approximately 48-72 hours apart and most trials were completed approximately 3 days apart (M=2.65, SD=0.76 days). Participants were instructed to maintain consistent dietary and sleep habits, and to avoid any other physical activity for the entire day of their visits to the lab. Participants were scheduled at approximately the same time of day for visits 3-5 in order to reduce diurnal variation in SIT performance and the lead experimenter (MJS) and one assistant experimenter were present for all exercise trials. The experimenters only interacted with participants to provide instructions, take measures, and ensure their safety during the experimental protocols, and did not provide any additional verbal encouragement. In order to control for motivational
influence by the experimenter, the same scripted set of instructions were provided throughout each exercise trial by the same male experimenter (MJS).

Following their final exercise trial, participants completed the post-experimental questionnaire.

4.2.8 Audio Selection and Editing

Music selection. Music was selected by the experimenters based on the criteria outlined by Karageorghis, Priest, Terry, Chatzisarantis, and Lane (2006) and with reference to Karageorghis’ (2016) model pertaining to music selection in the domain of exercise and sport. Sixteen asynchronous motivational songs that fit the general epoch (within the last 10 years), genre (pop, rock, hip-hop), and tempo (fast: 132-142 bpm) criteria were carefully chosen by the researchers and the top three musical selections with the highest motivational ratings were identified using a music rating panel. The music rating panel was comprised of eight British nationals who were not involved in the experimental phase of the study, but were representative of the population sampled for the study. As outlined in a paper by Karageorghis et al. (2006), panel members listened to 90-s of excerpts of the 16 songs and were asked to assess the extent to which each piece of music would motivate them during a 3 x 20s “all-out” SIT protocol by responding to each item of the Brunel Music Rating Inventory-3 (BMRI-3; Karageorghis, 2008). The BMRI-3 is a tool designed to assess the motivational qualities of musical pieces, with total possible scores ranging from 6 to 42 (Karageorghis, 2008). See Appendix C.2. for a complete list of all 16 musical selections included in the rating panel and Appendix C.3. for the BMRI-3 with instructions. The three songs with the highest average motivational ratings, according to each of the three genres, were as follows: (Pop) “Let’s Go” by Calvin Harris ft. Ne-Yo, 2012 (M=32.63, SD=3.66),
(Rock) “Bleed it Out” by Linkin Park, 2007 ($M=32.38$, $SD=4.60$), and (Hip-hop) “Can’t Hold Us” by Macklemore & Ryan Lewis ft. Ray Dalton, 2011 ($M=32.13$, $SD=4.61$).

**Music editing.** Each song was edited to last for a total of 7min in order to match the duration of the warmup, sprints, and recovery periods. The tempo of each song was edited slightly (if necessary) in order to remain within a fast tempo range (e.g., Karageorghis, 2016; Karageorghis et al., 2011) and within 7 bpm of each other: “Let’s Go” (original bpm = 128, edited to 135); “Bleed it Out” (original bpm = 140, not edited), and “Can’t Hold Us” (original bpm = 146, edited to 142). In order to create 7-min versions of the songs, the entire song or portions of each song were looped and edited slightly. All songs were downloaded from Apple’s iTunes Store (Apple Inc., 2017) and were edited by the first author (MJS) using Apple’s GarageBand (Apple Inc., 2017).

**Podcast selection and editing.** An audio podcast that was devoid of musical qualities (https://www.youtube.com/watch?v=Y-Unq3R--M0) was shortened from its original 10 min duration to 7 min. The podcast was narrated by a British male who discussed a brief history of consumerism.

The volumes of each audio file were standardized by using iTunes and a dB meter before being exported to an iPod Nano (7th Generation, Apple Inc.). Next, the volume was measured using the dB meter and set at 72 dBA from the ear level at which participants would be sitting on the bike. This volume was selected following pilot testing in order to ensure the sound quality was sufficient, the experimenters could hear and record the scale measures accurately, and to maintain effective communication with participants during the experimental procedures.
4.2.9 Statistical Analyses

Condition by time repeated measures ANOVAs were performed to examine differences between the three exercise conditions over time. First, differences in RPE and HR were assessed throughout the exercise protocol (warm-up, sprint 1, rest 1, sprint 2, rest 2, sprint 3). Second, differences in peak and mean power output were assessed during the three sprint bouts (sprint 1, sprint 2, sprint 3). Third, differences in FS and FAS were assessed pre-exercise and throughout the exercise protocol (pre-exercise, warm-up, sprint 1, rest 1, sprint 2, rest 2, sprint 3). Fourth, differences in FS and FAS were assessed from pre-exercise to post-exercise (pre-exercise and 0-min, 5-min, and 10-min post-exercise).

Separate one-way repeated measures ANOVAs were conducted to assess differences between the three conditions for PACES, liking, and motivation. Finally, two one-way repeated measures ANOVAs were conducted to assess differences between the three conditions for FS and FAS pre-exercise.

Due to the directionality of the hypotheses for FS, PACES, HR, and power output, significant main effects of condition were followed by simple contrasts, with the music condition defined as the comparator (Field, 2013). When significant main effects of time were detected, simple contrasts were used to test for differences, with the first measurement time point serving as the comparator. When sphericity was violated, the Greenhouse-Geisser correction was applied (Field, 2013). The magnitude of the observed effects were reported as partial eta squared ($\eta^2_p$), as recommended by Lakens (2013). While Cohen (1988) has provided benchmarks for interpreting $\eta^2$ (0.01 = small, 0.06 = medium, 0.14 = large), using these benchmarks to interpret $\eta^2_p$ effect sizes for repeated measures designs is not consistent with the statistical assumptions used to formulate the benchmarks (Lakens, 2013). As such,
there are currently no universally accepted benchmarks for interpreting the magnitude of $\eta_p^2$ (Lakens, 2013).

Based on gender differences in power output between men and women (e.g., Mayhew & Salm, 1990), gender was initially included as a between-subjects factor in the analyses for peak and mean power output in order to test for its potential moderating effects. No condition by gender, or condition by time by gender interactions were found for peak or mean power output, suggesting that the effects of the three conditions did not vary by gender. Thus, data were collapsed across men and women for the final analyses regarding power output. SPSS version 21.0 was used for all analyses, and significance was set at $p<0.05$.

4.3 Results

4.3.1 Participants

Twenty-six participants completed the entire study. Two female participants completed the study and received full compensation (i.e., a £50 honorarium), but their data were not used for analyses due to anomalous data (one expressed experiencing extreme life stress unrelated to the study that resulted in large fluctuations in baseline psychological responses between visits and another was fasting for religious reasons and her power output between visits was significantly impacted by her fatigue due to fasting). One male participant withdrew from the study unexpectedly following his first lab visit (for an undisclosed reason) and his data were not included in the analyses. In total, 24 participants (12 males, 12 females) were included in the analyses and their characteristics are presented in Table 4.1. Due to technical difficulties, HR data were missing from one male participant, which were not included in the HR analyses.
4.3.2 Psychological Measures

Affect. A one-way repeated measures ANOVA showed no differences in FS scores pre-exercise across the three exercise conditions ($p=0.16$, $\eta_p^2=0.08$). A 3 (condition) by 7 (time points: pre-exercise, warm-up, sprint 1, rest 1, sprint 2, rest 2, sprint 3) repeated measures ANOVA on pre- and in-task FS showed significant main effects of condition [$F(2, 46)=3.53$, $p=0.04$, $\eta_p^2=0.13$], and time [$F(1.79, 41.16)=16.74$, $p<0.01$, $\eta_p^2=0.42$] (see Figure 4.1). However, there was no significant condition by time interaction ($p=0.68$, $\eta_p^2=0.03$). The contrasts for condition revealed that, over the course of the SIT trial, FS responses were more positive in the music condition in comparison to the no audio control ($p=0.03$, $\eta_p^2=0.18$). Although FS responses tended to be more positive over the course of the SIT trial in the music condition compared to the podcast control, these differences were not statistically significant ($p=0.11$, $\eta_p^2=0.11$). Contrasts for time indicated that FS scores significantly increased from pre-exercise to warm-up ($p<0.01$, $\eta_p^2=0.39$) and decreased from pre-exercise to sprint 2 ($p=0.01$, $\eta_p^2=0.25$) and sprint 3 ($p<0.01$, $\eta_p^2=0.43$), with no differences in FS from pre-exercise to sprint 1, rest 1, and rest 2 ($ps>0.05$) across all three conditions.

A 3 (condition) by 4 (time points: pre-exercise and 0-min, 5-min, and 10-min post-exercise) repeated measures ANOVA on pre- to post-task FS showed only a significant main effect of time [$F(2.23, 51.33)=4.65$, $p=0.01$, $\eta_p^2=0.17$] (see Figure 4.1). None of the other main effects or interactions were significant ($ps>0.05$). The contrasts for time detected that FS did not change from pre-exercise to 0-min post-exercise ($p=0.73$, $\eta_p^2=0.01$), but significantly increased from pre-exercise to 5-min ($p=0.01$, $\eta_p^2=0.24$) and 10-min post-exercise ($p<0.01$, $\eta_p^2=0.27$; see Figure 4.1) across all three conditions.
Arousal. A one-way repeated measures ANOVA showed no differences in FAS scores pre-exercise across the three exercise conditions (p=0.62, \( \eta_p^2=0.02 \)). A 3 (condition) by 7 (time points: pre-exercise, warm-up, sprint 1, rest 1, sprint 2, rest 2, sprint 3) repeated measures ANOVA on pre- and in-task FAS showed only a significant main effect of time [F(2.67, 61.38)=81.00, p<0.01, \( \eta_p^2=0.78 \)] (see Figure 4.2). None of the other main effects or interactions were significant (ps>0.05). Contrasts for time indicated that FAS scores significantly increased from pre-exercise to all other time points during exercise (ps<0.01) across all three conditions.

A 3 (condition) by 4 (time points: pre-exercise and 0-min, 5-min, and 10-min post-exercise) repeated measures ANOVA on pre- to post-task FAS showed only a significant main effect of time [F(2.01, 46.33)=4.44, p=0.02, \( \eta_p^2=0.16 \)] (see Figure 4.2). None of the other main effects or interactions were significant (ps>0.05). The contrasts for time revealed that, FAS did not change from pre-exercise to 0-min (p=0.75, \( \eta_p^2=0.01 \)) or 5-min (p=0.24, \( \eta_p^2=0.06 \)) post-exercise, but significantly decreased from pre-exercise to 10-min post-exercise (p=0.02, \( \eta_p^2=0.21 \); see Figure 4.2) across all three conditions.

Exercise enjoyment. Mean enjoyment scores differed between the three conditions, F(2, 46)=3.41, p=0.04, \( \eta_p^2=0.13 \) (see Figure 4.3). Enjoyment was higher for the music (M=89.58, SD=17.33) than podcast (M=83.92, SD=19.49; p=0.04, \( \eta_p^2=0.18 \)) and no audio (M=85.28, SD=17.92; p=0.04, \( \eta_p^2=0.17 \)) controls.

4.3.3 Psychophysical Measures

Perceived exertion. A 3 (condition) by 6 (time points: warm-up, sprint 1, rest 1, sprint 2, rest 2, sprint 3) repeated measures ANOVA on RPE showed only a significant main effect for time, F(5, 115)=21.50, p<0.01, \( \eta_p^2=0.48 \) (see Figure 4.4). None of the other main
effects or interactions were significant \(p>0.05\). Contrasts for time indicated that RPE scores significantly increased from warm-up to all other time points during exercise \(ps<0.01\) across all three conditions.

4.3.4 Physiological Measures

Heart rate. A 3 (condition) by 6 (time points: warm-up, sprint 1, rest 1, sprint 2, rest 2, sprint 3) repeated measures ANOVA on HR showed significant main effects for condition \([F(1.55, 34.15)=5.35, \, p=0.02, \, \eta^2_p=0.20]\) and time \([F(2.38, 52.28)=438.32, \, p<0.01, \, \eta^2_p=0.95]\) (see Figure 4.5). However, there was no significant condition by time interaction \(p>0.05\). The contrasts for condition revealed that, over the course of the SIT trial, HR responses were elevated in the music condition in comparison to the podcast \(p=0.02, \, \eta^2_p=0.23\) and no audio \(p=0.03, \, \eta^2_p=0.21\) controls. Contrasts for time indicated that HR responses significantly increased from warm-up to all other time points \(ps<0.01\) across all three conditions.

Peak power output. A 3 (condition) by 3 (time points: sprint 1, sprint 2, sprint 3) repeated measures ANOVA on peak power output showed significant main effects of condition \([F(2, 46)=4.44, \, p=0.02, \, \eta^2_p=0.16]\) and time \([F(2, 46)=4.96, \, p=0.01, \, \eta^2_p=0.18]\) (see Figure 4.6). However, there was no significant condition by time interaction \(p>0.05\). The contrasts for condition revealed that, over the course of the SIT trial, peak power output was higher in the music condition in comparison to the podcast \(p=0.02, \, \eta^2_p=0.23\) and no audio \(p=0.01, \, \eta^2_p=0.25\) controls. Contrasts for time indicated that peak power output decreased from sprint 1 to sprint 2 \(p=0.05, \, \eta^2_p=0.16\) and sprint 3 \(p<0.01, \, \eta^2_p=0.26\) across all three conditions.

Mean power output. A 3 (condition) by 3 (time points: sprint 1, sprint 2, sprint 3) repeated measures ANOVA on mean power output showed only a significant main effect of
time [F(1.42, 32.65)=18.25, p<0.01, \(\eta_p^2=0.44\)] (see Figure 4.7). None of the other main
effects or interactions were significant (ps>0.05). Contrasts for time indicated that peak
power output significantly decreased from sprint 1 to sprint 2 (p<0.01, \(\eta_p^2=0.44\)) and sprint 3
(p<0.01, \(\eta_p^2=0.49\)) across all three conditions.

4.3.5 Post-Experimental Measures

**Liking.** Mean liking scores differed between the three experimental conditions, F(2, 46)=21.50, p<0.01, \(\eta_p^2=0.48\). The liking scores were higher during the music (\(M=7.83, SD=1.76\)) than the podcast (\(M=5.67, SD=2.41; p<0.01, \eta_p^2=0.32\)) and no audio (\(M=3.75, SD=1.92; p<0.01, \eta_p^2=0.69\)) controls, indicating that participants liked the music while it was playing during SIT.

**Motivation.** Mean motivation scores differed between the three experimental conditions, F(2, 46)=71.63, p<0.01, \(\eta_p^2=0.76\). The motivation scores were higher during the music (\(M=8.04, SD=1.12\)) than podcast (\(M=3.21, SD=1.84; p<0.01, \eta_p^2=0.83\)) or no audio (\(M=3.00, SD=1.74; p<0.01, \eta_p^2=0.84\)) controls, indicating that participants felt highly motivated while music was playing during SIT.

**Music genre selection.** Eight participants indicated no genre preference, 8 selected pop, 6 selected rock and 2 selected hip-hop.

4.4 Discussion

The main findings from the present study were that, among a sample of insufficiently active adults, listening to motivational music during SIT led to higher post-exercise enjoyment of SIT, elevated HR responses during SIT, and enhanced peak power output when compared to podcast or no audio control conditions. Further, affective responses tended to be more positive over the course of the SIT trial in the music condition in comparison to the
control conditions, and affect increased from pre-exercise to 5-min and 10-min post-exercise across all conditions. This is the first study to demonstrate the psychological, psychophysical, and physiological effects of researcher-selected motivational music during performance of a practical SIT protocol among a sample of insufficiently active adults.

4.4.1 Affective Responses

Consistent with the hypotheses and the results of previous studies (e.g., Hutchinson et al., 2011; Stork et al., 2015), affective responses were more positive over the course of the SIT trial in the music condition compared to the no audio control condition. Although affect tended to be more positive in the music condition compared to the podcast control, these differences were not statistically significant. Taken together, these findings suggest that listening to motivational music during a practical SIT protocol has the potential to induce more positive affective responses to the exercise, even for less active individuals.

Importantly, this finding has meaningful implications as a large number of researchers have suggested that the positive effects of music on feeling states may contribute to improved exercise adherence (see Karageorghis & Priest, 2012b).

The finding that affect tended to be more positive throughout the music condition in comparison to the control conditions is compelling given that participants also showed elevated HR and greater peak power in the music condition. In other words, an apparent increase in physical exertion during the music condition did not lead to more negative in-task affective states. However, peak power only represents the initial burst of power output during a WAnT sprint, and there were non-significant between-condition differences in mean power. Thus, short and brief increases in peak power alone may not have been sufficient enough to elicit more negative affective states during SIT. This finding is consistent with
previous research showing increases in peak and mean power output while listening to music during single (Hutchinson et al., 2011) or repeated WAnT sprints (Stork et al., 2015), with no cost to in-task affect.

Affective responses became significantly more positive from pre-exercise to 5-min and 10-min post-exercise, regardless of exercise condition. This post-exercise affective “rebound” to more positive states is consistent with previous research (e.g., Ekkekakis, Hall, & Petruzzello, 2008; Stork et al., 2018; Stork et al., 2015) and the predictions of the dual-mode theory (Ekkekakis, 2003). Although the use of recuperative music during the 3-min cool-downs or post-exercise was not evaluated in the current study, future research may benefit from examining the effects of recuperative music on affective states post-exercise.

4.4.2 Exercise Enjoyment

In line with the hypotheses and previous research (Stork et al., 2015), post-exercise enjoyment of SIT was higher in the music condition compared to the control conditions. This finding is important as enjoyment has been identified as a key moderator of the intention-behaviour relationship (Rhodes & Quinlan, 2018), and a predictor of positive exercise attitudes (Martin Ginis et al., 2006; Stork & Martin Ginis, 2017) and exercise behaviour (Rhodes et al., 2009). Individuals who intend to participate in exercise because they enjoy it are more likely to sustain their exercise intentions and carry out their intended exercise behaviour (Rhodes & Quinlan, 2018). Moreover, the use of music during SIT has been shown to improve enjoyment and attitudes towards SIT, which may have important implications for strengthening intentions towards SIT (Stork & Martin Ginis, 2017). Therefore, if insufficiently active people are more likely to enjoy SIT exercise while listening
to music, they may in turn be more likely engage in, and adhere to, SIT exercise again in the future (see also Stork et al., 2015; Stork & Martin Ginis, 2017).

### 4.4.3 Perceived Exertion

Consistent with the hypotheses and previous research (Stork et al., 2015), there were no differences in RPE between the three conditions. Similar to the results of Stork et al. (2015), this finding is intriguing because, even though participants achieved elevated HR responses and greater peak power output in the music condition, they perceived equal levels of physical exertion across conditions. These findings are also consistent with other studies that found music elicited higher power output during a single “all-out” WAnT sprint despite participants reporting non-significant differences in RPE between music and no music conditions (e.g., Chtourou, Jarraya, Aloui, Hammouda, & Souissi, 2012; Hutchinson et al., 2011). Collectively, such findings align with the perspective that music may not be as effective at influencing psychophysical states (i.e., RPE) at high exercise intensities because attentional processing becomes predominated by heightened physiological states (e.g., Karageorghis & Priest, 2012a; Rejeski, 1985; Tenenbaum, 2001).

### 4.4.4 Heart Rate Responses

A novel finding of the current study was that HR was elevated in the music condition compared to the control conditions. This is the first study to measure HR responses during acute SIT exercise when performed with music. Previous studies have documented increases in circulating levels of epinephrine (Yamamoto et al., 2003) and elevated HR responses (Eliakim et al., 2007) while fast tempo music was played prior to an “all-out” WAnT sprint, but such physiological responses were only detected during the warm-up periods and music
was not played during the WAnT performance. To our knowledge, this is also the first study to find elevated HR responses over the course of a SIT protocol performed with music.

One possible explanation for the current findings can be linked to the concept of entrainment. *Entrainment* refers to the natural tendency for humans to alter the frequency of their biological rhythms, such as HR, toward that of musical rhythms (Karageorghis, 2016). Based on this concept, it is plausible that participants’ HRs increased in response to the fast tempo music that was being played during SIT. Further, the fast tempo (135-142 bpm) music used in the present study falls within the ideal tempo range for high-intensity exercise based on research examining the relationship between exercise HR and music tempo preferences using cycle ergometry (Karageorghis et al., 2011). Considering that participants reported being highly motivated during SIT in the music condition, it is also possible that they were motivated to physically push themselves harder, at a slightly higher intensity, which would have been reflected by elevated HR responses. Thus, the cumulative effects of fast tempo music and high levels of motivation may explain the increased HR responses found in the music condition.

### 4.4.5 Power Output

Consistent with our hypotheses and previous research (Hutchinson et al., 2011; Stork et al., 2015), peak power output was higher in the music condition compared to the control conditions. However, contrary to hypotheses, there were no differences in mean power output between music and the control conditions. While the non-significant mean power findings are inconsistent with the previous SIT study (Stork et al., 2015), they are consistent with other studies investigating the effects of fast tempo music on a single WAnT sprint performance (e.g., Eliakim et al., 2007; Yamamoto et al., 2003). For the current study, it
appears that music was particularly effective at motivating participants with an initial burst of power at the start of each 20-s WAnT sprint, but this initial burst did not seem to persist throughout each of the three sprints. While the effects of music may be enough to motivate participants to start a WAnT sprint powerfully, it is possible that this effect diminishes as the exercise progresses and physiological fatigue predominates (Hutchinson et al., 2011; Stork et al., 2015). In addition, it is conceivable that the ergogenic effects of music during SIT may be less effective in insufficiently active individuals who are non-anaerobically trained and less accustomed to the buildup of lactate during SIT (Hutchinson et al., 2011).

It has been suggested that a unique element to applying music to a SIT protocol is that it can elicit both pre-task (warm-up and rest periods) and in-task (during sprints) effects, and these additive effects may explain why the impact of music can persist over the course of multiple sprint bouts (Stork et al., 2015). However, unlike the previous study which implemented a traditional 4 x 30-s SIT protocol with a 2-min and 30-s warm-up and 4-min rest periods (Stork et al., 2015), the present study implemented a practical SIT protocol with fewer sprint bouts (3) and shorter warm-up (2-min), sprint (20-s), and rest (2-min) durations. It may be that the reduced duration of the warm-up and rest periods reduced the potency of the music’s pre-task effects. In addition, fewer sprint bouts and shorter sprint durations may have limited the potential for the effects of music to be noticed over the course of the SIT protocol. Nevertheless, the ergogenic effects of music on peak power output were still apparent in this study despite such potential mitigating factors.

### 4.4.6 Study Strengths

There are several strengths of the current study. This is the first study to examine the psychological, psychophysical, and physiological effects of motivational music during a
practical 3 x 20-s SIT protocol among insufficiently active adults. This study builds upon the fundamental basis of a previous study (Stork et al., 2015), but provides novel contributions by replicating findings using a different participant sample and SIT protocol, and by accounting for previously stated limitations. Specifically, researcher-selected music with high motivational ratings (both a priori and post hoc) and standardized epoch and tempo was applied during SIT, a non-musical audio control condition (i.e., podcast) was included to isolate the effects of motivational music from the effects of an auditory distraction, and continuous HR data were collected throughout each of the exercise trials. Further, the application of music in this study was novel because, although researcher-selected music was implemented, participants were provided with the option to select which genre they preferred. To our knowledge, this hybrid approach with carefully standardized music options and the allowance of some choice for participants has not been used before. This method minimized the likelihood that participants listened to music they strongly disliked while also controlling for the musical characteristics, such as tempo. Analysis of the questions administered at the end of the study indicated that the music was perceived as being highly motivating and well-liked among participants. These methodological features contribute to the novelty of the study and also extend what is known about the effects of music during exercise and the conditions in which these effects occur.

The present study followed rigorous methodology in order to mitigate potential confounds and to tease out the effects of the music intervention. Some studies investigating the effects of music on WAnT performance have failed to include a familiarization trial or adequate recovery between exercise trials (e.g., Brohmer & Becker, 2006; Pujol & Langenfeld, 1999). For this study, two familiarization trials were completed prior to the
experimental trials in order to minimize any learning effects and to ensure participants fully understood the experimental procedures and measures. Experimental lab visits were separated by a minimum of 2 days and participants were asked to maintain consistent dietary and sleep habits and to avoid physical activity for the entire day preceding their experimental trials. This was completed in order to eliminate the effects of exercise fatigue and to minimize any differences between participants or the experimental trials. Additionally, an effort was made to conceal the true purpose of the study by not informing participants that music or audio stimuli would be played during the study in order to reduce the potential for experimental bias due to the anticipation of the music. Consistent with previous recommendations (Stork et al., 2017), numerous other methodological decisions were made in order to reduce possible confounders. For example, interactions with participants were scripted for all lab visits, participants were familiarized with and reminded about the differences between the scale measures at the start of each lab visit, diurnal variation between experimental trials was controlled for, and the lab setup, procedures, and environment were carefully standardized. Taken together, these methodological considerations allowed for a rigorous test of the study hypotheses.

### 4.4.7 Study Limitations

This study is not without its limitations. While a podcast about the history of consumerism was selected for the podcast control condition due to its non-musical and relatively impartial attributes, it was not possible to standardize individual responses to the podcast. For instance, some participants may prefer to listen to podcasts during exercise in general or may have had a personal interest (or disinterest) in the podcast topic. As such, it is possible that the podcast condition may have elicited unintended (positive or negative)
psychological or physiological responses from participants during the SIT protocols. However, this possibility seems unlikely given that the post-experimental measures showed that the music condition was superior to the podcast control condition in terms of liking ($M=7.83$ vs. $5.67$ out of 10, respectively) and motivation ($M=8.04$ vs. $3.21$ out of 10, respectively).

For this study, any significant main effects of condition or time were followed by simple contrasts. While this approach was taken due to the directionality of the study hypotheses (Field, 2013), the use of simple contrasts did not allow for comparisons between the two control conditions (i.e., podcast and no audio) or between all specified timepoints for some analyses (e.g., sprint 2 vs. sprint 3). These other comparisons were not conducted because they were not part of our main research question, and the study was not powered for these additional analyses. However, investigators may want to include these comparisons in their future research questions and analyses. For instance, studies investigating the effects of music on affective responses to SIT can test differences in affect at specific points of the SIT exercise experience that may be sensitive to change or may be considered the most consequential (e.g., positive or negative peaks, end states; Decker & Ekkekakis, 2017; Stork et al., 2017).

Given that this was an acute study of the effects of music during SIT, we cannot determine if the effects of music during SIT were, in part, due to novelty effects or will persist over time. Future studies assessing the continued effects of music on SIT over the longer term are recommended. Likewise, the SIT trials for this study were completed in a tightly controlled lab environment, so investigators are encouraged to evaluate the effects of music in more ecologically valid settings outside of the lab.
4.5 Summary

While SIT may be one of the most time-efficient forms of exercise and has been shown to provide meaningful health benefits, its “all-out” intensity can induce feelings of displeasure during exercise, which may discourage future participation. However, the use of music during SIT has the potential to enhance people’s psychological and physiological responses to SIT. The current study found that listening to researcher-selected music during a practical SIT protocol led to higher enjoyment and enhanced power output among insufficiently active adults. Further, HR responses were elevated and affective responses tended to be more positive over the course of the SIT trials performed in the music condition in comparison to the control conditions. These findings indicate that the psychological and physiological benefits of listening to self-selected music during SIT previously found in active people can also be experienced by insufficiently active people. Collectively, the application of music during SIT has the potential to increase feelings of pleasure during SIT, improve the enjoyment of SIT, and enhance performance of SIT for insufficiently active people, which may ultimately lead to better adherence to SIT exercise.
Table 4.1. Participant characteristics.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Overall N=24</th>
<th>Women n = 12</th>
<th>Men n = 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>24.08 ± 4.61</td>
<td>26.08 ± 5.12</td>
<td>22.08 ± 3.09</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>69.92 ± 14.95</td>
<td>60.70 ± 7.94</td>
<td>79.13 ± 14.80</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>173.16 ± 11.01</td>
<td>164.33 ± 5.48</td>
<td>182.00 ± 7.29</td>
</tr>
<tr>
<td>BMI (kg·m⁻²)</td>
<td>23.09 ± 2.68</td>
<td>22.41 ± 2.05</td>
<td>23.76 ± 3.14</td>
</tr>
<tr>
<td>Predicted VO₂max (mL·kg⁻¹·min⁻¹)</td>
<td>39.2 ± 8.5</td>
<td>40.7 ± 10.6</td>
<td>37.6 ± 5.8</td>
</tr>
</tbody>
</table>

Note. Values are presented as mean ± SD. BMI = body mass index; VO₂max = maximal oxygen uptake.
Figure 4.1. Feeling Scale responses (M±SE) before, during, and following the music, podcast, and no audio trials, plotted over time. 0-Post, 0-min post-exercise; 5-Post, 5-min post-exercise; 10-Post, 10-min post-exercise.
Figure 4.2. Felt Arousal responses (M±SE) before, during, and following the music, podcast, and no audio trials, plotted over time. 0-Post, 0-min post-exercise; 5-Post, 5-min post-exercise; 10-Post, 10-min post-exercise.
Figure 4.3. Post-exercise enjoyment (M±SE) of the music, podcast, and no audio trials. *p < 0.05
Figure 4.4. Rating of Perceived Exertion responses (M±SE) during the music, podcast, and no audio trials, plotted over time.
Figure 4.5. Heart rate responses (M±SE) during the music, podcast, and no audio trials, plotted over time. 0-Post, 0min post-exercise.
Figure 4.6. Peak power output (M±SE) across each sprint during the music, podcast, and no audio trials.
Figure 4.7. Mean power output (M±SE) across each sprint during the music, podcast, and no audio trials.
Chapter 5: General Discussion

The overarching purpose of this dissertation was to provide new insight on the ongoing debate about interval exercise by comprehensively evaluating the existing research evidence and examining the psychological and behavioural implications of interval exercise participation among physically inactive adults. First, a scoping review was conducted in Chapter 2 to provide the first systematic synthesis of the existent research evidence on the psychological responses to interval exercise. Forty-two articles were reviewed, findings were extracted, important issues and gaps were identified, and key recommendations for future research in the area were made. Several of the recommendations and gaps identified were used to inform the subsequent studies in Chapter 3 and Chapter 4.

Second, a mixed-methods experimental approach was used in Chapter 3 to study inactive participants’ psychological responses to acute bouts of interval and continuous exercise performed in a lab setting and their subsequent real-world exercise behaviour. This study was the first to examine the psychological responses to a practical 3 x 20-s SIT protocol, to investigate the relationship between acute psychological responses to HIIT and SIT and subsequent real-world HIIT and SIT exercise behaviour, and to take a qualitative approach to studying inactive people’s experiences with interval exercise in the lab and in naturalistic environments.

Finally, a repeated-measures crossover design was used in Chapter 4 to study the effects of motivational music on the psychological, psychophysical and physiological responses to a practical interval exercise protocol among insufficiently active adults. This was the first study to demonstrate that the application of researcher-selected music during practical 3 x 20-s SIT can increase feelings of pleasure during SIT, improve the enjoyment of
SIT, and enhance performance of SIT for insufficiently active people. Together, these studies have addressed gaps and limitations, and contributed valuable new knowledge to the interval exercise literature. The purpose of this final chapter is to highlight the theoretical, methodological, and practical contributions of this dissertation, along with the research limitations, and future research directions.

5.1 Theoretical Contributions

5.1.1 Affect-Behaviour Relationship

The assumption that negative affective responses to interval exercise will decrease the likelihood of continued participation has been identified as one of the most contentious aspects of the debate about interval exercise (e.g., Robertson-Wilson et al., 2017). This assumption is largely based on the tenets of the dual-mode theory (Ekkekakis, 2003) and research involving continuous exercise (Ekkekakis et al., 2011; Rhodes & Kates, 2015), but has been untested in the interval exercise literature. As such, Chapter 3 of this dissertation directly addressed this assumption by providing the first test of whether acute affective responses to HIIT and SIT exercise predict actual HIIT and SIT behaviour over a subsequent 4-week period. While we found that in-task affect during MICT predicted MICT behaviour over the next 4 weeks, we did not find this relationship to hold true for in-task affect during HIIT and SIT and subsequent HIIT and SIT behaviour (Stork et al. 2018). These findings provide a critical contribution to the application of the dual-mode theory to the study of interval exercise by showing that there may differences in the affect-behaviour relationship between interval and continuous exercise.

By acknowledging that affect may not predict behaviour the same way for interval exercise as it does for continuous exercise, we can start to reconsider some of the current
approaches that are being used to test the affect-behaviour relationship. For instance, while there has been suggestion about the most meaningful aspects of people’s affective responses to measure that can be used to predict exercise behaviour in general (i.e., negative or positive peaks, slopes, end points; Decker & Ekkekakis, 2017), it is possible that these aspects may not translate over to the interval exercise experience in particular. In the discussion of the findings from Chapter 3, it was suggested that the fluctuations in affect experienced during HIIT and SIT (due to the inclusion of rest periods between bouts) may complicate how affect is used to predict behaviour because affect does not follow the same gradual decline over time that is observed during MICT (Stork et al., 2018). This is an important point because it may help explain why the affect-behaviour relationship seems to differ between interval and continuous exercise and provides rationale for researchers to consider devising ways to capture the more complex changes that occur in affect during interval exercise protocols and their subsequent association with future interval exercise behaviour.

The affect-behaviour and qualitative findings in Chapter 3 also contribute to the idea that we should not underestimate the importance of individuals’ reflections and cognitive appraisals of their exercise experiences. Dual-process theories, such as the dual-mode theory, are named as such because they acknowledge that behavior is influenced by both Type 1 Processes which tend to be more automatic, heuristic, and reflexive, and Type 2 Process which are more slow, deliberate, and reflective (Evans & Stanovich, 2013). In the interval exercise debate, there has been such a strong emphasis on the role of affect, a Type 1 process, that the role of Type 2 processes have been seemingly overlooked. Drawing from the Discussion in Chapter 3, we must not forget the important interplay between the dual-processes that occur when people make decisions about whether they choose to engage in
interval or continuous exercise behaviour (or no exercise at all). Thus, the findings from Chapter 3 highlight the need to think beyond a direct relationship between in-task affect and behaviour, perhaps by incorporating social cognitive elements that account for people’s cognitions regarding in-task affect. This notion aligns well with the recently introduced Affective-Reflective Theory (ART) of physical inactivity and exercise (Brand & Ekkekakis, 2018).

The ART aims to explain and predict decisions people make about exercise-related behaviour. It builds on previous theories by still emphasizing the role of automatic affective valuation of exercise (a Type 1 process), “but without losing sight of the fact that cognitive insight and more complex reflection are important and necessary to long-term changes in exercise behaviour as well” (Brand & Ekkekakis, 2018, p. 49). In other words, the ART accounts for the role of reflective evaluation (a Type 2 process) in addition to affect when individuals ultimately make decisions about whether they remain physically inactive or decide to engage in exercise behaviour.

Taken together, the findings from Chapter 3 and recognition of the role of Type 2 processes in theoretical applications underscore the importance of incorporating both affective responses and cognitions into theoretical approaches to studying the affect-behaviour relationship with regard to interval exercise. The results also support a call for more research to examine the interaction between affect and cognition when people make decisions about participating in interval and continuous exercise.

5.1.2 Music and Exercise Theory

This dissertation makes two important contributions to the theoretical understanding of music and exercise. First, the selection and application of motivational music in Chapter 4
was guided by Karageorghis’ (2016) latest model of the study and application of music in exercise and sport. The model was applied to the research question using the three key categories of variables within the model: 1) musical factors (e.g., fast tempo, genre choice); 2) moderators (e.g., British participant sample, supramaximal exercise intensity of SIT); and 3) consequences (e.g., affect, enjoyment, power output). For example, fast tempo (135-142 bpm) music was selected for the study based on previous evidence that it is ideal to match fast tempo music to high-intensity exercise (Karageorghis, 2016; Karageorghis et al., 2011). Further, it was necessary to ensure the music selected was rated as highly motivational to a British sample given the supramaximal nature of the SIT protocol and that music’s impact on high-intensity exercise appears to predominate from the motivational qualities of the music (Hutchinson & Karageorghis, 2013; Karageorghis, 2016). Consequently, the study in Chapter 4 shows that Karageorghis’ (2016) model of the study of music in exercise and sport can be applied to SIT among insufficiently active individuals. This is a significant contribution to theory and research on music and exercise because it provides an excellent illustration of how the model can be applied and helps lay the foundation for future research to investigate similar applications of music to different interval exercise protocols and among less active samples.

Second, by including a non-musical audio (i.e., podcast) control condition in Chapter 4, we showed that the benefits of music during SIT are indeed a function of the qualities of the motivational music as opposed to the effects of a simple auditory distraction. This makes an important contribution to theory development in the music and exercise literature because it supports the notion that the psychological effects of music during high-intensity exercise are driven by music’s ability to motivate as opposed to its ability to dissociate attention away
from physiological sensations (Atkinson et al., 2004; Hutchinson & Karageorghis, 2013). Further, this finding also fills a gap identified in the broader field of research on the neurochemical and psychological effects of music in general, where it has been suggested that “Future work would also benefit from distinguishing the effects of music itself from other possible factors, such as simple distraction” (Chanda & Levitin, 2010; p. 186).

5.1.3 Theoretical Contributions: Final Thoughts

Although an array of theoretical perspectives has been used in studies investigating the psychological responses and behavioural consequences of interval exercise, it is important to identify common-ground among such theories and models. Based on what has been found across this thesis, Michie’s COM-B system of behaviour change (Michie et al., 2011) is a framework that is recommended for future research aiming to examine the psychological responses to interval exercise and interval exercise behaviour. Unlike many of the other theories or models mentioned earlier in this dissertation, this framework can be applied not only to the individual level, but also to the group and environmental level, which have been largely overlooked in the interval exercise research to date. It is important to acknowledge factors at the group and environmental level that may play an important role in influencing exercise behaviour change. For example, according to the COM-B, “Opportunity is defined as factors that lie outside the individual that make the behaviour possible or prompt it” (Michie et al., 2011, p. 4). To support this notion, the qualitative analyses from Chapter 3 illustrated that individuals may require access to certain exercise resources and guidance from others in order to engage in HIIT or SIT exercise on their own.

Further, an individual’s capability to engage in interval exercise can be influenced by both their psychological and physical capacities, which are both factors that have been
carefully considered throughout this dissertation. For instance, participants may require specific knowledge and skills before they can effectively try HIIT or SIT. Finally, the COM-B recognizes that motivation encompasses both automatic (Type 1) and reflective (Type 2) processes. This aspect of the COM-B is consistent with other dual process models (e.g., dual-mode theory, ART) and should be applied to future research in the interval exercise literature. Overall, the COM-B framework should be used in future studies in order to broaden our understanding of interval exercise behaviour at the group and environmental level, while also accounting for important motivational factors that have been studied to date.

5.2 Methodological Contributions

The scoping review of interval exercise research conducted in Chapter 2 identified several important methodological inconsistencies in the use of measurement and interval exercise protocols. These inconsistencies have, in part, fueled the ongoing debate (Stork et al., 2017). Such issues stress the necessity for greater methodological rigour in the study of the psychological responses to interval exercise (Stork et al., 2017). The following is an overview of some of the key methodological contributions of this dissertation.

5.2.1 Measurement

The scoping review identified affect and exercise enjoyment as the most commonly measured psychological constructs in interval exercise studies, with the FS (Hardy & Rejeski, 1989; n=13) and PACES (Kendzierski & DeCarlo, 1991; n=17) being the most commonly used measures. Considering the inconsistencies in measures used across studies (Stork et al., 2017) and the important role that affect and enjoyment play in the interval exercise debate, these findings highlight a point of consistency and provide rationale for why these two measures should be used in future studies. While it is important to avoid selecting
measures with the sole purpose of having consistency with past research (e.g., Ekkekakis, 2013), there is value in “using appropriate measures consistently to allow for a body of literature to develop” (Robertson-Wilson et al., 2017, p. 2). Following this line of reasoning, it has been suggested that the findings from the scoping review about what measures of affect and enjoyment have been used are particularly helpful for study replication and comparison when examining the psychological responses to interval exercise (Robertson-Wilson et al., 2017). On a similar note, the use of the FS and PACES in Chapters 3 and 4 also provides a valuable contribution to the literature, as the findings for these measures can be compared to other studies that have used the same measures.

However, in order to promote study replication and to effectively make comparisons across interval exercise studies, there also needs to be more consistency in how and when such measures are taken. Given the variability in how and when measures have been administered across interval exercise studies, the scoping review provided specific recommendations for how to minimize confounders and to improve the accuracy of measurement timing during interval exercise protocols. For example, suggestions were made on how to minimize common method variance when prompting responses to single-item scales such as RPE, FS, or FAS and how to minimize confounders in the research environment. In addition, recommendations were provided to encourage researchers to obtain affect ratings at the end of recovery periods and at the end of the high-intensity work intervals whenever possible in order to capture the time-sensitive fluctuations in affect that occur during acute interval exercise sessions. These recommendations should meaningfully contribute to the future study of interval exercise because they provide clear direction on how to improve measurement consistency, increase confidence in study findings, and facilitate
replication and comparison of findings between studies. Importantly, these suggestions were incorporated when designing and conducting the studies presented in Chapters 3 and 4.

5.2.2 Standardization of Exercise Protocols

The scoping review also provided guidelines for how researchers can navigate the inconsistent use of terminology when categorizing interval and continuous exercise protocols, the differences in the specific protocols used within exercise categories, and the variability in the relative exercise durations when drawing comparisons about interval and continuous exercise. An increased awareness and understanding of these issues in the interval exercise literature can serve to reduce confusion for researchers when they attempt to compare findings between studies or attempt to draw conclusions from studies. Additionally, highlighting these issues can also encourage researchers to put more thought into what terminology they use to define exercise protocols and what exercise protocols they choose to implement in their studies based on their research questions.

For example, the MICT, HIIT, and SIT protocols studied in Chapter 3 were defined using the guidelines provided in the scoping review and were carefully selected based on evidence that inactive people can elicit similar physical benefits from these protocols over several weeks of training. In addition, total exercise duration and energy expenditure were deliberately not controlled for between MICT, HIIT, and SIT in order to capture the exercise intensity-duration trade-off between the three protocols and the possible time-saving appeal of HIIT and SIT in comparison to MICT (Stork et al., 2018). In Chapter 4, the practical SIT protocol studied was selected based on previous evidence of the impact of music during SIT (Stork et al., 2015) and by considering the feasibility of the protocol for the insufficiently active sample being studied (see Vollaard & Metcalfe, 2017). These methodological
examples from Chapters 3 and 4 show how the recommendations provided in Chapter 2 can be used to help guide further studies in the area. The examples also provide thoughtfully designed, evidenced-based exercise protocols that can be replicated in future research.

5.2.3 Applying Researcher-Selected Music to Interval Exercise

While Stork et al. (2015) was the first study to examine the effects of *self-selected* music during SIT, the study in Chapter 4 was the first study to examine the effects of *researcher-selected* music during SIT. Further, a hybrid approach to the application of researcher-selected music was implemented by providing participants with the opportunity to choose the genre of music they would listen to during the exercise. The findings from this study provide a significant contribution to the music and interval exercise literature because they demonstrate that music that is thoughtfully selected by researchers using Karageorghis’ (2016) model can be effective at enhancing psychological and physiological responses to SIT.

Another important methodological innovation of the Chapter 4 study was the inclusion of a second control condition (i.e., non-musical audio podcast) in the study design. This condition was included in order to differentiate the effects of motivational music from the effects of an audio distraction. Future researchers can adopt both the hybrid approach to music selection and the second control condition as methodological approaches when applying music to exercise protocols. Together, these features of the study design in Chapter 4 provide important methodological contributions to the area of music and exercise in general, and to the area of music and interval exercise in particular.
5.3 Bridging the Research Gaps

Some of the major gaps that currently exist in the interval exercise literature were identified in Chapter 2. Recommendations to bridge these gaps were provided in order to inform subsequent research and to shed light on the debate regarding the appropriateness of interval exercise for the general population. Several of these recommendations were implemented in Chapters 3 and 4.

First, it was recommended that qualitative research be undertaken to evaluate the psychological implications of interval exercise (Stork et al., 2017). The mixed-methods study described in Chapter 3 was the first to qualitatively assess people’s experiences across MICT, HIIT, and SIT exercise. The study provided new insights into inactive people’s perceptions of, and factors that may influence their ability to engage in, these forms of exercise. For instance, the qualitative findings provided a richer understanding as to why quantitative assessments of enjoyment may have been similar between protocols, and why participants may have struggled to complete HIIT or SIT exercise on their own, outside of the lab. The quantitative measurements included in the study would not have been able to capture that some participants felt that the rest periods during HIIT or SIT made the exercise less boring than MICT or that some participants avoided completing HIIT or SIT outside the lab because they found it difficult to track those workouts on their own. The qualitative approach used in Chapter 3 provides meaningful new knowledge about people’s experiences with MICT, HIIT, and SIT, while also setting the pace for qualitative methods to be implemented in future interval exercise research.

Second, it was recommended that more research is needed to examine people’s participation in interval exercise outside of controlled laboratory settings and in the real-
world (Stork et al., 2017). Hence, participants’ MICT, HIIT, and SIT free-living exercise
behaviour, outside of the lab, were measured over a 4-week follow-up in the study reported
in Chapter 3. These measures provided valuable preliminary data regarding inactive people’s
real-world interval exercise patterns, barriers and facilitators, locations, and modalities. For
example, some participants discussed their experiences completing HIIT at home in the form
of stairclimbing or using body weight exercises. These data not only enhance our
understanding of inactive people’s exercise patterns, but also further our knowledge about
the types of exercise inactive people may prefer to participate in outside of the lab and some
of the reasons why. Future research investigating various forms of interval exercise
behaviour completed over the longer term and using different measures of physical activity
behaviour (e.g., accelerometers, self-report, interviews) are recommended.

A third recommendation from the scoping review (Stork et al., 2017), which is also
consistent with the recommendations provided from other researchers (Jung et al., 2016;
Robertson-Wilson et al., 2017), is a need for more interdisciplinary research in the area of
interval exercise. The studies in this dissertation were conducted in collaboration with
experts in the areas of library science, qualitative methods, musicology, and exercise
physiology. These collaborations have enhanced the overall quality and rigour of the research
and have furthered our knowledge about interval exercise more than what could have been
achieved by experts from any of those disciplines working in isolation.

5.4 Practical Implications

The results of the dissertation studies provide several practical implications for
researchers, health care and exercise practitioners (e.g., physical therapists, fitness
instructors), and the largely inactive general population. Specifically, Chapter 2 provides a
comprehensive breakdown of the various issues, considerations and gaps in the interval exercise research and provides several practical recommendations for researchers to use in the future. For example, the above-mentioned methodological recommendations can help provide researchers with guidance on which psychological outcomes to measure and how to make methodological decisions when designing and carrying out a new research study (e.g., deciding which exercise protocols to test and how to administer the measures selected).

Chapter 3 highlights the notion that “one size does not fit all” – it is critical to consider individual differences when it comes to exercise preferences (Stork et al., 2018). This message is important because it illustrates that people have varied psychological responses to and preferences for MICT, HIIT, and SIT exercise that should be considered when prescribing exercise to inactive individuals. For example, lab-based testing of people completing single sessions of interval or continuous exercise may be used to help determine individualized exercise prescriptions that are more conducive to high levels of enjoyment and continued exercise participation. Further, exercise and health care practitioners can provide people with opportunities to try various forms of interval and continuous exercise using different modalities as a way of exposing people to different forms of physical activity that they may be inclined to enjoy and engage in. Such practical implications can be particularly meaningful because they acknowledge the role of individual preferences.

The qualitative findings from Chapter 3 provide a deeper understanding of a wide range of factors (e.g., barriers, facilitators, perceptions, feasibility) that may impact inactive people’s ability to participate in interval exercise in real-world settings. These findings can be used to provide practical recommendations for inactive individuals interested in trying interval exercise. For instance, we now know that people tend to have difficulty
timing/monitoring interval exercise workouts by themselves and may lack the knowledge of how to do interval exercise when they are unsupervised on their own. Therefore, a simple recommendation for individuals interested in trying interval exercise is to remember to bring a device (e.g., phone, stopwatch) to time their work and rest periods when they plan an interval exercise session. Additionally, they can try interval exercise with an experienced friend that can help monitor their workout and show them how to it. A recommendation for fitness professionals could be to educate and advise clients on how to complete interval exercise when they are on their own and not under supervision.

Based on the findings from Chapter 4, listening to music during interval exercise may be recommended for insufficiently active individuals. The findings showed that music has the potential to evoke more positive affect and higher enjoyment, two outcomes that have been independently linked to increased exercise adherence (Karageorghis & Priest, 2012b; Stork et al., 2015; Stork & Martin Ginis, 2017). Further, music was also found to increase physical exertion during SIT, as reflected by elevated HR and greater peak power in the music condition. Taken together, the application of music to interval exercise may be a practical method to help insufficiently active people get a bit more out of their workout and may be used to encourage continued interval exercise participation. For example, if an individual was interested in trying interval exercise for their first time, they may benefit from listening to music with a fast tempo (~140 bpm) and a genre of their preference while completing the exercise.

5.5 General Limitations and Future Directions

While this dissertation has provided a comprehensive evaluation of the existing research and valuable new research on the psychological and behavioural implications of
engaging in interval exercise in physically inactive adults, there are some important limitations that should be acknowledged. One limitation is that while the participants included in Chapters 3 and 4 were all considered to be physically inactive, they were also young and healthy. Thus, the study results may not generalize to physically inactive individuals who are older or people with chronic conditions (e.g., obese/overweight, cardiometabolic disease, physically disabled). Although Chapter 2 showed that several studies have already examined the psychological responses to interval exercise protocols across a wide range of populations (e.g., post-cardiac rehabilitation, coronary artery disease, obese/overweight, spinal cord injury), future research is required to determine if the findings from the studies included in this dissertation can also be replicated in or generalized to such populations.

Another limitation is that the experimental studies in Chapters 3 and 4 were completed in tightly controlled, sterile laboratory environments and the exercise protocols were completed on specialized cycle ergometers. As a result, the in-lab study findings may not necessarily generalize to interval exercise protocols completed outside of a supervised lab setting and using different exercise modalities. Therefore, there is value for future research to investigate people’s acute psychological responses to interval exercise protocols that can be implemented in naturalistic environments using readily accessible exercise equipment (e.g., BWIT, stairclimbing). Notwithstanding, the 4-week follow-up behaviour reported in Chapter 3 does provide some initial insight into the real-world translatability of the MICT, HIIT, and SIT cycling protocols to other exercise modalities.

Based on key recommendations about how best to administer scale measurements (Stork et al., 2017), steps were taken to minimize common method variance between single-
item scales, reduce confounders in the research environment, and capture the time-sensitive fluctuations in affect occurring during the exercise trials. That being said, this approach was not without limitations and we were not able to account for all measurement recommendations made by Stork et al. (2017). For example, for pragmatic reasons, the RPE, FS, and FAS scales were posted up on a wall in front of participants (rather than placed in front of them at the time of response) and were not prompted in a randomized order. These methods were necessary because of the time-sensitivity of the work and rest periods for the HIIT and SIT protocols, the importance of ensuring participants were exercising at the desired intensities, and the small window of time for prompting and recording scale measures. Although several steps were taken to minimize potential confounds (e.g., scales were colour-coded, participants were familiarized with the differences between the scales during familiarization trails and at the beginning of each experimental trial), these methods may have led to some associated variance transfer between scales or to participants thinking about or anticipating their upcoming scale responses.

Another limitation worth noting is that the reports of affect were prompted immediately following the work bouts for HIIT and SIT, and not during the final few seconds, due to logistical constraints with collecting scale responses during high-intensity and “all-out” cycling efforts and to maintain consistency between HIIT and SIT. Consequently, it is possible that we may not have been able to truly capture the absolute peak negative affect at the end of each HIIT and SIT bout. However, steps were taken to ensure that we were capturing participants’ affective states during the work bouts as opposed to at the cessation of the exercise (e.g., explicit instructions were provided to participants to ensure they were reporting how they felt during the exercise bouts). Moreover, unlike some
previous studies (e.g., Frazão et al., 2016; Wood et al., 2016), affect was also recorded during the rest periods. Further, the absolute affective responses during HIIT and SIT reported appear to be comparable to, or more negative than, other reports of affect during interval exercise protocols completed by low active samples (e.g., Decker & Ekekkakis, 2017; Martinez et al., 2015), suggesting that peak/close to peak negative affective states were likely captured.

Although steps were taken to ensure confidence in the studies conducted in this dissertation, another limitation is that the methods and hypotheses of these studies were not pre-registered. A recently published commentary (Robertson-Wilson et al., 2017) highlighted the need for the replication and verification of study findings in the area of interval exercise and recommended that researchers should consider pre-registering studies as a means to address this need. Future research in this area would benefit from pre-registration for a variety of reasons, including reduced reporting and publication biases (van ’t Veer & Giner-Sorolla, 2016). Additionally, pre-registration would be particularly helpful in the context of the interval exercise debate, as it would foster greater theoretical scrutiny, methodological consistency, and certainty in the research findings (Robertson-Wilson et al., 2017). Nonetheless, the theoretical, measurement, and methodological parameters detailed in this dissertation can certainly be replicated and verified in future studies, and can be used to inform future research.

5.6 The Debate: Final Thoughts

Many of the findings and contributions from this dissertation shed new light on the debate about the appropriateness of interval exercise for the largely inactive general population. For example, the cumulative findings from the scoping review support the
viability of interval exercise as an alternative to continuous exercise from a psychological perspective. Further, our finding that inactive people can find interval exercise equally as enjoyable and preferable as continuous exercise adds further evidence to substantiate the conclusions made from the scoping review. Additionally, the finding that music can be effective at augmenting insufficiently active people’s psychological and physiological responses to SIT demonstrates the potential for music as a strategy to help promote continued participation in interval exercise.

Interestingly, the debate about interval exercise has also been framed as the “HIIT versus MICT” debate, revolving around a question of whether HIIT (or SIT) or MICT is the superior form of exercise with regard to enhancing health and promoting exercise adherence (e.g., Decker & Ekkekakis, 2017; Juneau, Hayami, Gayda, Lacroix, & Nigam, 2014). Considering our Chapter 3 findings that many inactive participants engaged in HIIT and/or SIT in addition to MICT when exercising on their own, framing the debate in terms of “HIIT versus MICT” may be misleading. Given that different forms of interval exercise can be integrated into people’s lifestyles in addition to continuous exercise, it would be more meaningful for the debate to move forward by framing research questions in terms of “HIIT and/or MICT.” This approach would place less emphasis on whether interval exercise is superior to continuous exercise, and place more focus on interval exercise as an exercise option – one that can be used concurrently with other forms of exercise, including continuous exercise.

Collectively, the findings and contributions of this dissertation bring us one step closer to resolving the debate about interval exercise. It appears that there is indeed a potential for interval exercise to have a place in exercise plans and programs for the general
population. Although interval exercise may not be preferred by all people, it can serve as a meaningful exercise option for many individuals.

5.7 Conclusion

This dissertation provided new insights that may help resolve the debate about the psychological and behavioural implications of advocating interval exercise for largely inactive populations by highlighting key issues, considerations, and gaps in the research area and by utilizing new methods to address them. Important theoretical advancements were made by providing an enhanced understanding of the affect-behaviour relationship for interval exercise and by offering new insight into the selection, application, and benefits of researcher-selected music during a SIT protocol. Key methodological contributions were made by addressing inconsistencies in the literature with respect to measurement and the standardization of interval exercise protocols, and by applying rigorous methodologies in order to improve study replication and comparison.

Notably, three major gaps in the research were filled by providing qualitative analyses of people’s experiences to interval and continuous exercise, evaluating participation in interval exercise in naturalistic settings outside of the lab, and by using interdisciplinary collaborations to enhance the quality and rigour of the research. Further, the findings from this dissertation provide several practical implications for researchers, exercise and health care practitioners, and the largely inactive general population. Finally, several important limitations in the dissertation studies were acknowledged and future directions that can be used to advance this research area were provided. In conclusion, the contributions from this dissertation not only provide a critical advancement to our understanding about the viability
of interval exercise and its potential to improve physical activity among largely inactive populations, but also acts as a springboard for future research to come.
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Appendices

Appendix A: Supplementary Material for Chapter 2

Appendix A.1. Complete Search Strategy for Medline database

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<td>4874</td>
<td>Advanced</td>
</tr>
<tr>
<td>2 (high intensity or sprint or interval or intermittent) and short duration and (train* or exercis*).mp.</td>
<td>435</td>
<td>Advanced</td>
</tr>
<tr>
<td>3 1 or 2</td>
<td>5222</td>
<td>Advanced</td>
</tr>
<tr>
<td>4 enjoy*.mp.</td>
<td>16885</td>
<td>Advanced</td>
</tr>
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<td>5 arousal.mp.</td>
<td>47292</td>
<td>Advanced</td>
</tr>
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<td>10 self efficacy/ or self efficacy.mp.</td>
<td>28788</td>
<td>Advanced</td>
</tr>
<tr>
<td>11 exercise behaviour?.mp.</td>
<td>1491</td>
<td>Advanced</td>
</tr>
<tr>
<td>12 exercise adherence.mp.</td>
<td>636</td>
<td>Advanced</td>
</tr>
<tr>
<td>13 affective response*.mp.</td>
<td>1583</td>
<td>Advanced</td>
</tr>
<tr>
<td>14 affect*.valence.mp.</td>
<td>411</td>
<td>Advanced</td>
</tr>
<tr>
<td>15 ((attitude* or intent*) adj2 exercis*).mp.</td>
<td>518</td>
<td>Advanced</td>
</tr>
<tr>
<td>16 or/4-15</td>
<td>512238</td>
<td>Advanced</td>
</tr>
<tr>
<td>17 3 and 16</td>
<td>226</td>
<td>Advanced</td>
</tr>
<tr>
<td>18 remove duplicates from 17</td>
<td>200</td>
<td>Advanced</td>
</tr>
</tbody>
</table>
Appendix A.2. Reference List of Secondary Research Sources


Appendix A.3. Flow-Chart of Systematic Literature Search

Citations from online database searches:
- MEDLINE: 200
- EMBASE: 232
- PsycINFO: 90
- SPORTDiscus: 189

Total citations downloaded to RefWorks: 711

Duplicate articles removed: 266

Non-duplicated citations screened: 445

Additional articles identified through other sources: 6

Articles excluded after title/abstract screen: 372

Full text assessed for eligibility: 79

Articles excluded after full text screen: 37

Articles included for review: 42
Appendix A.4. Reference List of Studies Included for Review


aerobic fitness and muscular endurance in females. *Applied Physiology, Nutrition, and Metabolism, 37*(6), 1124-1131.


Appendix A.5. Psychosocial Constructs Measured in Studies Included in the Scoping Review

<table>
<thead>
<tr>
<th>Construct Category</th>
<th>Number of studies</th>
<th>Number of measures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Affective Responses</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Affect</td>
<td>17</td>
<td>6</td>
</tr>
<tr>
<td>Arousal</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Mood</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td><strong>Enjoyment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enjoyment</td>
<td>22</td>
<td>5</td>
</tr>
<tr>
<td><strong>Exercise-related Social Cognitions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attitudes</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Exercise satisfaction</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Intentions</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Motivation</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Perceived competence</td>
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<td>1</td>
</tr>
<tr>
<td>Self-efficacy</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td><strong>Cognition &amp; Executive Function</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Choice-Response Time Task</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Inhibition</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Working memory</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Health-related Quality of Life</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perceived health</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Perceived stress</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Quality of life</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Satisfaction with life</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Exercise Preference &amp; Behaviour</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exercise adherence</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Exercise/PA behaviour</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Exercise preference</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rating of perceived exertion</td>
<td>26</td>
<td>4</td>
</tr>
</tbody>
</table>

*Note.* Number of studies refers to number of studies based on unique datasets.
Appendix B: Supplementary Material for Chapter 3

Appendix B.1. Exercise Log Sheet

<table>
<thead>
<tr>
<th>SUNDAY</th>
<th>MONDAY</th>
<th>TUESDAY</th>
<th>WEDNESDAY</th>
<th>THURSDAY</th>
<th>FRIDAY</th>
<th>SATURDAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration</td>
<td>Duration</td>
<td>Duration</td>
<td>Duration</td>
<td>Duration</td>
<td>Duration</td>
<td>Duration</td>
</tr>
</tbody>
</table>

**DON’T FORGET:** record which exercise protocol you participated in on each day, either: a) **END** = continuous *moderate*-intensity; b) **HIIT** (10x1-min *high*-intensity bouts, 1-min rest between); c) **SIT** (3x20-sec “all-out” bouts, 2-min rest between). If you completed a modified protocol or your own exercise protocol, please indicate this.

**Exercise:** A planned, structured, and repetitive bodily movement done to improve or maintain one or more components of physical fitness.
Appendix B.2. Semi-Structured Interview Questions

VISIT 1

In general, tell me what you think about…

(a) **Moderate-intensity endurance exercise** = continuous exercise at a moderate-intensity; 50min duration, including warm-up and cool-down.
   - What have you heard about this type of exercise, whether it be from the media, health provider, or friends and family?
   - Tell me how you feel about participating in this exercise during your own free time in the next 8 weeks, using any modality (e.g., bike, treadmill, elliptical, track, stairs, etc.).

(b) **High-intensity interval exercise** = 10 x 1-min high-intensity bouts, 1-min rest between each; 24min duration, including warm-up and cool-down.
   - What have you heard about this type of exercise, whether it be from the media, health provider, or friends and family?
   - Tell me how you feel about participating in this exercise during your own free time in the next 8 weeks, using any modality (e.g., bike, treadmill, elliptical, track, stairs, etc.).

(c) **Sprint interval exercise** = 3 x 20s “all-out” bouts, 2-min rest between each; 10min duration, including warm-up and cool-down.
   - What have you heard about this type of exercise, whether it be from the media, health provider, or friends and family?
   - Tell me how you feel about participating in this exercise during your own free time in the next 8 weeks, using any modality (e.g., bike, treadmill, elliptical, track, stairs, etc.).

VISITS 2-4

1) How did you feel (physically and psychologically) before, during and after this exercise protocol?

2) Tell me how you feel about completing this exact same exercise protocol during your own free time in the next 8 weeks, using any modality (e.g., bike, treadmill, elliptical, track, stairs, etc.).

3) Regular PA is recommended as a way to improve your health. What impact do you think participating in this type of exercise 3 times per week would have on your physical health?
FOLLOWING VISIT 4 ONLY (all 3 conditions completed at this point)

1) Compare and contrast your experiences during each exercise protocol (MICT/HIIT/SIT) you have completed in this study. (Remind them of each exercise protocol if they forget).

2) You indicated that you like the (MICT/HIIT/SIT) exercise protocol the most. Why do you like that particular exercise protocol the over the others?

3) You indicated that during your own free time (using any modality) you would choose to complete the (MICT/HIIT/SIT) exercise protocol the most. Why would you like to do that particular exercise protocol the over the others during your own time?

**If they list pros or cons: ask “any others?” and then ask, “do you think there would be any cons?” (or same thing vice versa).

VISIT 5 (Follow Up)

1) Which exercise protocol(s) did you complete over the past 4 weeks? Why did you choose to do that/those one(s)? Why didn’t you choose to do the other one(s)?

2) You previously indicated that you liked the (MICT/HIIT/SIT) exercise protocol the most. Do you still like that particular exercise protocol over the others? Why/why not?

3) What obstacles prevented you from participating in these types of exercise? Were these obstacles more apparent for one type of exercise over another?

4) If you were to have a personal trainer put you through a training program that consisted of 3 exercise sessions per week over several weeks, which type(s) of exercise would you choose to complete (MICT/HIIT/SIT)?

5) Would you prefer to exert higher levels of physical effort for a short period of time or exert a moderate level of physical effort for a longer period of time?

**Note: if they showed different preferences for one exercise in the lab vs. completed on their own (based on their exercise preference responses), ask them “I noticed that you reported a greater preference for (X) protocol when completed in the lab, but you preferred (X) protocol when you completed it one your own. Why is this the case?”
Before & After Questions (Repeat of Visit 1)

At the beginning of the study I asked you how you felt generally about these 3 exercise protocols. Now that you have experienced participating in this study, what do now think (generally) about…

a) **Moderate-intensity endurance exercise** = continuous exercise at a moderate-intensity; **50min** duration, including warm-up and cool-down.
   - Tell me how you feel about participating in this exercise during your own free time in the next 8 weeks, using any modality (e.g., bike, treadmill, elliptical, track, stairs, etc.).

b) **High-intensity interval exercise** = 10 x 1-min high-intensity bouts, 1-min rest between each; **24min** duration, including warm-up and cool-down.
   - Tell me how you feel about participating in this exercise during your own free time in the next 8 weeks, using any modality (e.g., bike, treadmill, elliptical, track, stairs, etc.).

c) **Sprint interval exercise** = 3 x 20s “all-out” bouts, 2-min rest between each; **10min** duration, including warm-up and cool-down.
   - Tell me how you feel about participating in this exercise during your own free time in the next 8 weeks, using any modality (e.g., bike, treadmill, elliptical, track, stairs, etc.).
Appendix C: Supplementary Material for Chapter 4

Appendix C.1. Liking and Motivation Items for Each Condition

Music Items

For each of the following items, think about your experience during the sprint interval exercise session where music was being played over the speakers.

Please rate how much you liked the music while it was played during that exercise session:

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>I did not like it at all</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>I liked it very much</td>
<td></td>
</tr>
</tbody>
</table>

Please rate how much the music motivated you while it was played during that exercise session:

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>It did not motivate me at all</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>It motivated me very much</td>
<td></td>
</tr>
</tbody>
</table>
Podcast Items

For each of the following items, think about your experience during the sprint interval exercise session where the podcast was being played over the speakers.

Please rate how much you *liked* the podcast while it was played during that exercise session:

1  2  3  4  5  6  7  8  9  10
I did not like it at all                                      I liked it very much

Please rate how much the podcast *motivated* you while it was played during that exercise session:

1  2  3  4  5  6  7  8  9  10
It did not motivate me at all                             It motivated me very much
No Audio Items

For each of the following items, think about your experience during the sprint interval exercise session where *no auditory stimulus* was played over the speakers.

Please rate how much you *liked* having no auditory stimulus during that exercise session:

1 2 3 4 5 6 7 8 9 10
I did not like it at all                         I liked it very much

Please rate how much having no auditory stimulus *motivated you* during that exercise session:

1 2 3 4 5 6 7 8 9 10
It did not motivate me at all                It motivated me very much
Appendix C.2. List of 16 Songs Included in the Music Rating Panel

<table>
<thead>
<tr>
<th>Song Title</th>
<th>Artist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Let’s Go</td>
<td>Calvin Harris ft. Ne-Yo</td>
</tr>
<tr>
<td>Can’t Hold Us</td>
<td>Macklemore &amp; Ryan Lewis ft. Ray Dalton</td>
</tr>
<tr>
<td>This is What You Came For</td>
<td>Calvin Harris ft. Rihanna</td>
</tr>
<tr>
<td>Believer</td>
<td>Imagine Dragons</td>
</tr>
<tr>
<td>Big for Your Boots</td>
<td>Stormzy</td>
</tr>
<tr>
<td>Five More Hours</td>
<td>Deorro ft. Chris Brown</td>
</tr>
<tr>
<td>Hit the Road Jack</td>
<td>Throttle</td>
</tr>
<tr>
<td>Break Free</td>
<td>Ariana Grande ft. Zedd</td>
</tr>
<tr>
<td>Bleed it Out</td>
<td>Linkin Park</td>
</tr>
<tr>
<td>Turn Up the Music</td>
<td>Chris Brown</td>
</tr>
<tr>
<td>Pursuit of Happiness (Steve Aoki Remix)</td>
<td>Kid Kudi</td>
</tr>
<tr>
<td>Howlin’ for You</td>
<td>The Black Keys</td>
</tr>
<tr>
<td>Let’s Go</td>
<td>Trick Daddy ft. Twista &amp; Lil’Jon</td>
</tr>
<tr>
<td>Don’t Wake Me Up</td>
<td>Chris Brown</td>
</tr>
<tr>
<td>Get Up (Rattle)</td>
<td>Bingo Players ft. Far East Movement</td>
</tr>
<tr>
<td>Thunderstruck (Crookers Remix)</td>
<td>ACDC</td>
</tr>
</tbody>
</table>
Appendix C.3. Brunel Music Rating Inventory-3

The Brunel Music Rating Inventory-3

This questionnaire is designed to assess the extent to which the piece of music you are about to hear would motivate you during sprint interval exercise (3 x 20s all-out sprints with 2 minutes of rest between each) on a stationary cycle. For our purposes, the word motivate means that you would want to pursue sprint interval exercise with greater intensity and push yourself harder. As you listen to the piece of music, indicate the extent of your agreement with the seven statements listed by circling one of the numbers to the right of each statement. Provide an honest response to each statement. Give the response that best represents your opinion, and avoid dwelling too long on any single statement.

Important Definitions:

Rhythm: the speed of the music and the way in which it is accented.
Melody: the tune or highest part of a piece of music.
Tempo: the rate or the speed of a piece of music

(Sample BMRI-3):

<table>
<thead>
<tr>
<th>Song 1</th>
<th>Is this song familiar? Y / N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title: Let's Go; Artist: Calvin Harris ft. Ne-Yo</td>
<td>Strongly disagree</td>
</tr>
<tr>
<td>1 The rhythm of this music would motivate me during sprint interval exercise.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>2 The style of the music (i.e., rock, pop, hip-hop, dance, jazz) would motivate me during sprint interval exercise.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>3 The melody (tune) of this music would motivate me during sprint interval exercise.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>4 The tempo (speed) of this music would motivate me during sprint interval exercise.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>5 The sound of the instruments used (i.e., guitar, synthesizer, saxophone) would motivate me during sprint interval exercise.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>6 The beat of this music would motivate me during sprint interval exercise.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>* Overall, this music would motivate me during sprint interval exercise.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
</tbody>
</table>
Appendix C.4. International Physical Activity Questionnaire

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the last 7 days. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the vigorous activities that you did in the last 7 days. Vigorous physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

1. During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, digging, aerobics, or fast bicycling?
   _____ days per week
   ☐ No vigorous physical activities ➔ Skip to question 3

2. How much time did you usually spend doing vigorous physical activities on one of those days?
   _____ hours per day
   _____ minutes per day
   ☐ Don’t know/Not sure

Think about all the moderate activities that you did in the last 7 days. Moderate physical activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

3. During the last 7 days, on how many days did you do moderate physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.
   _____ days per week
   ☐ No moderate physical activities ➔ Skip to question 5
4. How much time did you usually spend doing moderate physical activities on one of those days?

____ hours per day
____ minutes per day

☐ Don’t know/Not sure

Think about the time you spent walking in the last 7 days. This includes at work and at home, walking to travel from place to place, and any other walking that you have done solely for recreation, sport, exercise, or leisure.

5. During the last 7 days, on how many days did you walk for at least 10 minutes at a time?

____ days per week
☐ No walking ➔ Skip to question 7

6. How much time did you usually spend walking on one of those days?

____ hours per day
____ minutes per day

☐ Don’t know/Not sure

The last question is about the time you spent sitting on weekdays during the last 7 days. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

7. During the last 7 days, how much time did you spend sitting on a week day?

____ hours per day
____ minutes per day

☐ Don’t know/Not sure

This is the end of the questionnaire, thank you for participating.
Appendix D: Additional Study Materials

Appendix D.1. Physical Activity Readiness Questionnaire

**PAR-Q & YOU**

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>□</td>
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<td>□</td>
<td>□</td>
</tr>
<tr>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

### If you answered YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

* You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
* Find out which community programs are safe and helpful for you.

### If you answered NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:
- start becoming much more physically active — begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal — this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

### Delay becoming much more active:

- if you are not feeling well because of a temporary illness such as a cold or a fever — wait until you feel better; or
- if you are or may be pregnant — talk to your doctor before you start becoming more active.

### Please note:

If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

---

**Note:** This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

---

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Version 2, Feb 28, 2017

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## Appendix D.2. Borg’s Rating of Perceived Exertion Scale

<table>
<thead>
<tr>
<th>Rating</th>
<th>Description</th>
<th>Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Nothing at all</td>
<td>“No P”</td>
</tr>
<tr>
<td>0.3</td>
<td>Extremely weak</td>
<td>Just noticeable</td>
</tr>
<tr>
<td>0.7</td>
<td>Very weak</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Weak</td>
<td>Light</td>
</tr>
<tr>
<td>1.5</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Strong</td>
<td>Heavy</td>
</tr>
<tr>
<td>2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Very strong</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Extremely strong</td>
<td>“Max P”</td>
</tr>
<tr>
<td>6-9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Absolute maximum
- Highest possible
**Borg’s CR10 Scale Instructions**

**Basic Instruction:** 10, “Extremely strong – Max P”, is the main anchor. It is the strongest perception (P) you have ever experienced. It may be possible, however, to experience or to imagine something even stronger. Therefore, “Absolute maximum” is placed somewhat further down the scale without a fixed number and marked with a dot “.”. If you perceive an intensity stronger than 10, you may use a higher number.

Start with a verbal expression and then choose a number. If your perception is “Very weak,” say 1; if “Moderate,” say 3; and so on. You are welcome to use half values (such as 1.5, or 3.5, or decimals, for example, 0.3, 0.8, or 2.3). It is very important that you answer what you perceive and not what you believe you ought to answer. Be as honest as possible and try not to overestimate or underestimate the intensities.

**Scaling perceived exertion:** We want you to rate your perceived (P) exertion, that is, how heavy and strenuous the exercise feels to you. This depends mainly on the strain and fatigue in your muscles and on your feeling of breathlessness or aches in the chest. But you must only attend to your subjective feelings and not to the physiological cues or what the actual physical load is.

1 is “very light” like walking slowly at your own pace for several minutes.

3 is not especially hard; it feels fine, and it is no problem to continue.

5 you are tired, but you don’t have any great difficulties.

7 you can still go on but have to push yourself very much. You are very tired.

10 this is as hard as most people have ever experienced before in their lives.

- this is “Absolute maximum,” for example, 11 or 12 or higher.
Appendix D.3. Feeling Scale

Feeling Scale (FS)
(Hardy & Rejeski, 1989)

While participating in exercise, it is common to experience changes in mood. Some individuals find exercise pleasurable, whereas others find it to be unpleasant. Additionally, feeling may fluctuate across time. That is, one might feel good and bad a number of times during exercise. Scientists have developed this scale to measure such responses.

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>+5</td>
<td>Very good</td>
</tr>
<tr>
<td>+4</td>
<td></td>
</tr>
<tr>
<td>+3</td>
<td>Good</td>
</tr>
<tr>
<td>+2</td>
<td></td>
</tr>
<tr>
<td>+1</td>
<td>Fairly good</td>
</tr>
<tr>
<td>0</td>
<td>Neutral</td>
</tr>
<tr>
<td>-1</td>
<td>Fairly bad</td>
</tr>
<tr>
<td>-2</td>
<td></td>
</tr>
<tr>
<td>-3</td>
<td>Bad</td>
</tr>
<tr>
<td>-4</td>
<td></td>
</tr>
<tr>
<td>-5</td>
<td>Very bad</td>
</tr>
</tbody>
</table>
Appendix D.4. Felt Arousal Scale

<table>
<thead>
<tr>
<th>FELT AROUSAL SCALE (FAS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Svebak &amp; Murgatroyd, 1985)</td>
</tr>
</tbody>
</table>

Estimate here how aroused you actually feel. Do this by circling the appropriate number. By “arousal” we meant how “worked-up” you feel. You might experience high arousal in one of a variety of ways, for example as excitement or anxiety or anger. Low arousal might also be experienced by you in one of a number of different ways, for example as relaxation or boredom or calmness.

1  LOW AROUSAL

2

3

4

5

6  HIGH AROUSAL
Appendix D.5. Physical Activity Enjoyment Scale

**PHYSICAL ACTIVITY ENJOYMENT SCALE (PACES)**

Now that you have completed this physical activity protocol, we want to know how you enjoyed it. Think about how you are currently feeling about the workout you just completed as you respond to each of the following items. Please circle only one number for each item and try to respond as honestly as possible.

<table>
<thead>
<tr>
<th>I enjoyed it</th>
<th>1 2 3 4 5 6 7</th>
<th>I hated it</th>
</tr>
</thead>
<tbody>
<tr>
<td>I felt bored</td>
<td>1 2 3 4 5 6 7</td>
<td>I felt interested</td>
</tr>
<tr>
<td>I disliked it</td>
<td>1 2 3 4 5 6 7</td>
<td>I liked it</td>
</tr>
<tr>
<td>I found it pleasurable</td>
<td>1 2 3 4 5 6 7</td>
<td>I didn’t find it pleasurable</td>
</tr>
<tr>
<td>I was very absorbed in this activity</td>
<td>1 2 3 4 5 6 7</td>
<td>I was not at all absorbed in this activity</td>
</tr>
<tr>
<td>It was no fun at all</td>
<td>1 2 3 4 5 6 7</td>
<td>It was a lot of fun</td>
</tr>
<tr>
<td>I found it energizing</td>
<td>1 2 3 4 5 6 7</td>
<td>I found it tiring</td>
</tr>
<tr>
<td>It made me depressed</td>
<td>1 2 3 4 5 6 7</td>
<td>It made me happy</td>
</tr>
<tr>
<td>It was very pleasant</td>
<td>1 2 3 4 5 6 7</td>
<td>It was very unpleasant</td>
</tr>
<tr>
<td>I felt good physically while doing it</td>
<td>1 2 3 4 5 6 7</td>
<td>I felt bad physically while doing it</td>
</tr>
<tr>
<td>It was very invigorating</td>
<td>1 2 3 4 5 6 7</td>
<td>It was not at all invigorating</td>
</tr>
<tr>
<td>I was very frustrated by it</td>
<td>1 2 3 4 5 6 7</td>
<td>I was not at all frustrated by it</td>
</tr>
<tr>
<td>It was very gratifying</td>
<td>1 2 3 4 5 6 7</td>
<td>It was not at all gratifying</td>
</tr>
<tr>
<td>It was very exhilarating</td>
<td>1 2 3 4 5 6 7</td>
<td>It was not at all exhilarating</td>
</tr>
<tr>
<td>It was not at all stimulating</td>
<td>1 2 3 4 5 6 7</td>
<td>It was very stimulating</td>
</tr>
<tr>
<td>It gave me a strong sense of accomplishment</td>
<td>1 2 3 4 5 6 7</td>
<td>It didn’t give me a strong sense of accomplishment</td>
</tr>
<tr>
<td>It was very refreshing</td>
<td>1 2 3 4 5 6 7</td>
<td>It was not at all refreshing</td>
</tr>
<tr>
<td>I felt as though I would rather be doing something else</td>
<td>1 2 3 4 5 6 7</td>
<td>I felt as though there is nothing else I would rather be doing</td>
</tr>
</tbody>
</table>