

THE EFFECT OF GROUP SIZE ON SYNCHRONY
AND THE SYNCHRONY EFFECT

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ABSTRACT

Synchronization of behaviour has repeatedly shown to increase endorphin activity as measured by pain threshold (Cohen, Ejsmond-Frey, Knight, & Dunbar, 2010; Sullivan & Rickers, 2014). Although research on synchronous behaviour and the synchrony effect has noted instances of the synchrony effect in multiple physical activities (Cohen et al., 2010; Davis, Taylor, Cohen & Mesoudi, 2015; Kokal, Engel & Kirschner, 2011), it has only incorporated small group trials. Additionally no previous literature has investigated endorphin level subsequent to the immediate termination of exercise. The current study examined the effect of group size on the magnitude of the synchrony effect and explore the length of time the synchrony effect lasts. Thirty-three participants rowed 3 twenty minute time trials on a Concept II ergometer under three counterbalanced conditions - alone, paired and large group (n=12). Pain threshold, was assessed before, immediately post, 5 minutes post, and 10 minutes post each session. Contrary to previous research, a significant synchrony effect was not observed between the solo and group conditions. A significant positive change in pain threshold was reported at the 10 minute post exercise time point compared to the paired condition. This result suggests a longer lasting synchrony effect in a large group condition and that synchronous movement in large groups allows for individuals to exert themselves longer in such conditions.

Keywords: behavioural synchrony, endorphins, pain threshold, group effect

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CHAPTER 1: INTRODUCTION

Moving together is human nature. Humans have repeatedly demonstrated the inclination to synchronize their movements with those around them. Experiments examining postural sway (Shockley, Santana, & Fowler, 2003), walking (Nessler & Gilliland, 2009), and rocking chair movements (Richardson, Marsh, Isenhower, Goodman, & Schmidt, 2007), have found that people are naturally inclined to coordinate their movement with others. These findings have been replicated in more complex tasks, such as drumming (Kirschner & Tomasello, 2009; Kokal, Engel, Kirschner, & Keysers, 2011), swinging handheld pendulums (Richardson et al., 2007), and hand waving (Macrae, Duffy, Miles, & Lawrence, 2008), as well as tasks that require movements to be synchronized with external stimuli (Bood, Nijssen, van der Kamp, & Roerdink, 2013). The inclination to move synchronously have been found in children as young as two, who have been shown to impulsively synchronize themselves with the beat of a drum (Kirschner & Tomasello, 2009).

Synchronization between people can have a profound effect on social perception and cooperation. Miles, Nind and Macrae (2009) reported that individuals perceived the highest level of interpersonal rapport when synchrony was greatest in group strides during repeated walking trials. An increase in interpersonal attraction has also been cited by Hove and Risen (2009) between individuals who were more synchronized in a finger tapping experiment. Furthermore, Sullivan, Gagnon, Gammage and Peters (2015) found individuals who walked as part of a synchronized condition were more cooperative than individuals moving in a non-synchronous manner.

Research suggests that endorphin release can be derived as the potential mechanism

for the social effects of synchrony. Synchronous behavior, specifically strenuous synchronized movement, has been shown to elevate individuals' endorphin levels. Similar endorphin activity has been observed during instances of social bonding in humans and primates (Depue & Morrone-Strupinsky, 2005; Tarr, Launay, Cohen, & Dunbar, 2015; Weinstein, Launay, Pearce, Dunbar, & Stewart, 2016). Endorphin release can be experienced as a mild opiate "high", with a corresponding sensation of euphoric well-being accompanied by temperate analgesia (Stefano, Goumon & Casares, 2000). Endogenous opioids, in the form of endorphins, play an integral part in the anti-nociceptive system (Millan, 2002), which reduces the body's sensitivity to painful stimuli. Accordingly, pain threshold is commonly used as an indicator of endorphin activity as direct measurement of brain endorphins is only possible by virtue of invasive lumbar puncture (Boecker et al., 2008; Dearman & Francis, 1983). A reliable alternative, non-invasive endorphin assessment protocol, is the use of a blood pressure cuff to induce ischemic pain (Estebe, Le Naoures, Chemaly, & Ecoffey, 2000; Ryan & Kovacic, 1966).

Cohen, Ejsmond-Frey, Knight and Dunbar (2010) investigated the effects of synchrony on highly skilled male collegiate rowers using pre- and post- pain threshold tests as a means to measure endorphin activity. Cohen and colleagues found individuals elicited significantly higher changes in pain threshold when working in synchrony with their teammates than when performing the same workout alone. Consequently, Cohen et al. (2010) extrapolated that a "synchrony effect" occurs when vigorous activity is performed in synchrony and endorphin activity is increased.

The findings of Cohen et al. (2010) were replicated by both Sullivan and Rickers (2013) and Sullivan, Rickers and Gammage (2014). In the 2013 study, Sullivan and

Rickers concluded that participants' pain threshold increased after synchronous rowing with both teammates or strangers. In the 2014 study, the pre- and post- pain threshold of twenty-four individuals was examined during solitary, in-phase synchronized, and anti-phase synchronized rowing ergometer time trials. This study found that when individuals rowed in an in-phase synchronous condition, they reported a significantly greater increase (from pre- to post-activity) in pain threshold compared with either the solitary or anti-phase rowing conditions. In the discussion, the authors supported the notion of the synchrony effect being "a robust phenomenon" by alluding to a number of investigations in which a higher pain threshold is indicated for individuals after vigorous synchronized activity with others (Cohen et al., 2010; Sullivan & Rickers, 2013; Sullivan, Rickers, & Gammage, 2014).

One aspect of the synchrony effect that has yet to be explored is the effect of increased group size. Weinstein, Launay, Pearce, Dunbar and Stewart (2016) investigated endorphin activity of individuals who sang in a 'megachoir' condition, which consisted of 232 people compared to a small choir condition. Participants noted an increased sensation of inclusion and connectivity after a performance, additionally all experienced an increased pain threshold. However, no significant difference was found in pain threshold increase between the small and large choir conditions. However, the singing did not require any sort of movement, a common factor with each of the previous investigations.

The effects of vigorous synchronized movement, specifically increased endorphin activity as measured by pain threshold, has only been reported in synchronous groups of six or less. The current study will investigate if the endorphin effect described by both Cohen et al. (2010) and Sullivan et al. (2012; 2014) becomes more significant with a

larger group of synchronized individuals involved in strenuous activity.

CHAPTER 2: LITERATURE REVIEW

2.1 Social Interaction

Instantaneous social interaction is a core component of society and has never been more prominent than it is in today's world. Interaction is "the action or influence of people, groups, or things on one another" (Merriam-Webster, 2003), and is a complimentary event that requires at least two parties and only occurs when individuals mutually influence each other (Wagner, 1994). Human beings have relied on social interaction for survival since the beginning of time. It should not be surprising then, that social interaction has been repeatedly shown to have a profound effect on our emotional intelligence (Lopes, Brackett, Nezlek, Schütz & Sellin, 2004) and our view of both self (Fenigstein, 1979) and also those around us (Weinstein et al., 2016).

Social interactions can occur in a number of different manners. Conversing, communal eating, and spending time together are all methods of social interaction. Another captivating method of social interaction involves physical movement. Social movements, such as walking (Sullivan, Gagnon, Gammage and Peters, 2015) and dancing (Reddish, Fischer, & Bulbulia, 2013; Tarr et al., 2015), can have a momentous effect on how individuals feel about and interact with each other. Additionally, moving together or in synchronized sequence can magnify these effects. A considerable amount of literature supports the findings that positive social outcomes can be realized through imitation (Levine & Pesendorfer, 2007; van Baaren, Janssen, Chartrand, & Dijksterhuis, 2009) and synchronization (Davis, Taylor, Cohen, & Mesoudi, 2015; Miles et al., 2009; Sullivan et al., 2015). Van Baaren et al. (2009) investigated self-reported perceptions of individuals following interviews with an experimenter who mimicked their movements and body

language with slight delay. The results demonstrated that the imitation of body movements can cause a subject to feel more similar to others and to behave in a more prosocial manner. Additionally, Miles et al. (2009) found that walkers who synchronized their movements during moderate exercise experienced significantly higher levels of cooperation afterwards.

2.2 Synchrony

Bernieri and Rosenthal (1991) noted that synchrony refers to “the degree of congruence between the behavioral cycles of two or more entities.” Sebanz, Bekkering and Knoblich (2006) further described synchrony as a joint action “whereby two or more individuals coordinate their actions in space and time to bring about a change in the environment” (p. 73).

Synchrony is a phenomenon believed to be rooted in biology through evolution. Animal behaviourists have suggested that synchronous actions are vital for the survival of many animals and that they can facilitate learning (Fellner, Bauer, & Harley, 2006), enable mutual responses to danger (Tóth & Duffy, 2005), and strengthen alliances among packs (Connor, 2007; Connor & Krützen, 2015). Dunbar and Shultz (2010) speculated that in certain pair-bonded animals, failure to coordinate behavior could potentially lead to physical separation, thereby increasing an individual’s risk for predation or reducing one’s likelihood of reproduction. In humans specifically, individuals who demonstrated greater social synchrony tendencies (i.e., singing and dancing), would be more likely to reap the benefits of social society (i.e., marriage and safety), which would increase the probability of longevity and reproduction (Haidt, Seder, & Kesebir, 2008).

The tendency humans have to coordinate their movements and actions with others has been speculated to serve “as the basis for our social connectedness with others” (Marsh, Richardson, & Schmidt, 2009). Accordingly, Sullivan and Rickers (2013) identified synchronized movement as a core component of numerous institutions in human society. The most prominent examples include military units marching in step, dancing and singing at religious and community events (Anshel & Kipper, 1988; Gorer, 1972; McNeill, 1995). Reddish et al. (2013) claimed that “these rhythmic practices have played a long standing role in cultural evolution and bolster feelings of solidarity which increases prosocial behavior.”

It has been theorized that synchronized cultural practices, such as singing, dancing and marching, have supported societies’ progress throughout evolution. Empires were built around synchronous activities. Social ties with neighbouring communities, often facilitated by song and dance, provided security by sharing information about resources and potential dangers (Whallon, 2006). Armies drill soldiers to march in step; religions around the globe incorporate song and dance into their practice; sports teams incorporate synchronous movements into their warm-ups. Anthropologists and sociologists have speculated that rituals involving synchronous activity may produce positive emotions that weaken the psychological boundaries between the self and the group of co-actors (Wiltermuth & Heath, 2009). Group coordination can establish a basis for social cohesion amongst individuals that keep together in time, moving large muscles together and singing or dancing rhythmically. McNeil (1995) denoted the term “muscular bonding”, describing the euphoric feeling that is experienced following rhythmic muscular movement. An expanding body of work supports these findings, repeatedly concluding

that synchronized movements can substantially increase prosocial feelings (Dunbar, Kaskatis, Macdonald & Barra, 2012; Kokal et al., 2011; Sullivan et al., 2015).

There is an extensive body of work that suggests social synchrony operates by means of augmenting feelings of solidarity which therefore increases pro-social behaviours. Lumsden, Miles and Macrae (2014) investigated individuals performing arm curls in synchronous and asynchronous conditions. The results of the study revealed that individuals felt better about themselves post synchronous movement as compared to asynchronous movement and furthermore, perceived a greater level of solidarity with their synchronous partner. Reddish et al. (2013) found that synchronous movements were associated with greater pro-sociality towards not only the group performing the synchronous movement, but also to non-participants. Marsh et al. (2009) concluded that an individual's biological desire to coordinate with other individuals is fundamental, serving as the basis for our social connectedness to others. In this regard, behavioral synchrony provides one possibility through which these inter-personal links can be formed (Rickers, 2014).

Humans are naturally inclined to coordinate their movements with one-another. This phenomenon has been described in studies examining postural sway (Shockley et al., 2003), walking (Nessler & Gilliland, 2009), and rocking chair movements (Richardson et al., 2007). The inclination to coordinate movements has also been observed in more complex tasks, such as drumming (Kirschner & Tomasello, 2009; Kokal et al., 2011), swinging handheld pendulums (Richardson et al., 2007), and hand waving (Macrae et al., 2008), as well as tasks that require movements to be synchronized with external stimuli (Bood et al., 2013).

Synchronization of goals and the actions needed to achieve success, are an essential component to successful social interactions between humans. Examinations of these interactions have occurred in both intentional and unintentional circumstances. Richardson et al. (2007) performed a number of experiments on rocking chair motions, examining the moments of individuals in purposefully synchronous and random conditions. The study concluded that people are naturally inclined to synchronize with others because of the internal constraints of the self-organizing dynamics of a coupled oscillator system. Notwithstanding, interpersonal synchrony appears to be of universal importance and little is known about the neural basis of this phenomenon. Presumably, reaching a coordinated state can indicate potential connectedness of a pair of individuals. An investigation by Lakin, Jefferis, Cheng and Chartrand (2003) demonstrated that mimicry and synchrony are associated with greater rapport between pairs and foster cooperation. Haidt, Seder and Kesebir (2008) noted a similar finding as it pertained to human evolution, describing individuals that were more disposed to social synchrony as more likely to experience the social benefits of protection and increased likelihood of reproduction, while limiting their risk of predation or lesser hunting capacity (Dunbar & Shultz, 2010).

2.2.1 In-phase vs Anti-phase Synchrony.

Research examining interpersonal synchrony has primarily compared two modes of coordination: in-phase and anti-phase (Haken, Kelso, & Bunz, 1985; Miles et al., 2009; Sullivan et al., 2014). This could be attributed to findings by Miles et al. (2009), which demonstrated an increased level of rapport between subjects, associated with movements closest to in-phase and anti-phase synchrony cycles. In-phase coordination is

the most natural, and occurs when two individuals perform a task while moving simultaneously together in time. Consequently, the actions of each individual would consistently be at equivalent points of the movement cycle throughout the motion. An example of in-phase synchrony would occur if two individuals were on a swing set, and while swinging, they arrived at the back and front position of their swings at the same time. In contrast, anti-phase synchrony would demonstrate an opposing movement pattern. In an anti-synchronous condition, coordinated individuals would be at the opposite points of the movement cycle at the same time. Back to the swing set example, anti-phase synchrony would occur when one person has swung as far forward as the swing can reach, as the other person is at the back of their motion.

It has been repeatedly found that the degree of coordination, specifically its continuous stability, can play a role in fundamental aspects of social exchange where stability refers to the continuity of coordination without disruption (Miles et al., 2009). Research examining multiple movements has found instances of spontaneous and unintentional in-phase or anti-phase synchronization in walking (van Ulzen, Lamoth, Daffertshofer, Semin, & Beek, 2008), limb movements (Issartel, Marin, & Cadopi, 2007), postural sway (Shockley et al., 2003), and handheld pendulum swinging (Richardson et al., 2007). In another study with handheld pendulums, participants synchronized their pendulum swinging without instruction in either an in-phase or an anti-phase condition (Schmidt & O'Brien, 1997). This state of continuous synchronous movements has been labelled as the "mooring effect" by Marsh et al. (2009). Marsh further explained that "the effect allows individuals with a somewhat poorer ability to coordinate with the rhythms of the world to be better able to coordinate their actions with the environments if

movements of others pull them into their orbit” (p. 329). It is imperative to understand that while in-phase and anti-phase synchrony are both considered stable modes of coordination, Haken et al. (1985) specified that in-phase synchronized coordination is an overall “attractor state”.

Sullivan, Rickers and Gammage (2014) examined both in-phase and anti-phase synchrony and their ramifications on the subsequent synchrony effect. Twenty-two participants completed the study, which consisted of a 30 minute indoor rowing trial in each of the 3 counter-balanced conditions: alone, in-phase synchrony, and anti-phase synchrony. Pain threshold was used as a proxy measurement for endorphin release and was assessed immediately before and after each session. Participants experienced a significantly higher change in pain threshold following the in-phase synchrony session than in either of the other two conditions. These results highlight that the synchrony effect only occurs during instances of in-phase synchrony. It also further discredits the notion that social presence may be solely responsible for the effect of synchrony on pain threshold.

2.3 Effects of Synchrony

Moving together clearly elicits a profound effect on people. It is speculated that the importance of synchronized movement in humans is biologically ingrained due to its evolutionary importance. Synchronization between people has also been shown to influence their subsequent positive social feelings towards one another, compared with asynchronous or solo conditions (Hove & Risen, 2009). Participants who perform a task in synchrony, report increased feelings of liking (Hove & Risen, 2009), interpersonal

trust (Launay, Dean, & Bailes, 2013), cooperation (Sullivan et al., 2015), and willingness to aid their partner (Valdesolo & Desteno, 2011).

In recent years, research examining the pro-social effects of synchrony has become more prominent. One of the most common findings is the positive effect synchronous actions can have on inter-personal cooperation. Kokal et al. (2011) investigated the pro-social commitment of drummers who performed in synchrony and out of synchrony with others. Participants who drummed in synchrony demonstrated significantly greater pro-social commitment than their asynchronous counterparts. In 2015, Sullivan et al. examined individuals walking in either a synchronized or non-synchronized condition. In a post-walk social investment game, used to measure inter-personal cooperation, the participants in the synchronized condition demonstrated significantly greater cooperation than the non-synchronized participants. In a similar study, Wiltermuth and Heath (2009) examined participants who walked in a synchronized condition, and reported feeling more connected and trusting of their peers.

Likewise, Davis et al. (2015), in a study on the effect of synchrony on cooperation and bondedness, examined individuals on a collegiate rugby team in one of three warm up conditions: solo, synchronized and non-synchronized warm-up. The individuals in the synchronized conditions benefitted from cooperative social bonding, which additionally led to an increase in subsequent anaerobic performance.

Non-strenuous coordinated actions have also demonstrated similar effects on group cooperation as strenuous synchronous movement. Subjects who sang together showed significantly greater post-activity cooperation than did subjects who sang alone (Wiltermuth & Heath, 2009). Furthermore, Weinstein et al. (2016) reported increased

feelings of inclusion, connectivity, and social closeness in choir members following 90 minutes of well-rehearsed singing. Synchronized activities, both vigorous and not, have been shown to enhance individuals' perception of social closeness. The above findings indicate that synchronous activity can stimulate increased inter-personal cooperation and promote a greater sense of group identity. Davis et al. (2015) proposed that these perceptions of togetherness and cohesion, activated by behavioural synchrony, could also activate a social support based analgesic mechanism. The authors further suggested that during strenuous, synchronous exercise, individuals could push themselves harder and for longer periods of time due to increased pain thresholds and decreased perceptions of muscular and psychological fatigue.

Regardless of whether individuals mimic one-another's actions or if movements are extemporaneously performed in coordination there appears to be a direct correlation to increased feelings of inter-personal attraction and pro-social behavior. Additionally, Valdesolo, Ouyang and Desteno (2010) concluded that synchrony leads individuals to believing that their synchronous co-actors are increasingly similar to themselves in terms of personal attributes and beliefs. These instances of perceived similarity may lead individuals to experience subconscious feelings of being united with other synchronous individuals or in extreme cases, sentiments of a joint-identity.

2.4 Effects of Endorphins

While there are a number of proposed hypotheses regarding how synchrony affects individuals, one of the most plausible suggests that increased endorphin levels are responsible. In a 2011 review article, Machin and Dunbar noted "there is considerable evidence to suggest that (the brain) opioids play a fundamental role in sociality" (p. 985).

Accordingly, synchronous behaviours, have repeatedly been shown to elevate participants' endorphin levels, commonly associated with social bonding in primates and other mammals (Cohen et al., 2010; Dunbar, 2010; Dunbar & Shultz, 2010; Sullivan & Rickers, 2013). Endorphins are naturally occurring neuro-chemicals, which possess properties similar to morphine, that bind to pain receptors and consequently block pain sensation. Endorphins are primarily synthesized and stored in the anterior pituitary gland. The principle function of endorphins is to “inhibit the transmission of pain signals by binding to opioid receptors (particularly of the mu sub-type) at both pre- and post-synaptic nerve terminals, primarily exerting their effect through presynaptic binding” (Stein, 1995). Consequently, a cascade of interactions results in inhibition of the release of tachykinins, a key protein involved in the transmission of pain (Goodman and Gilman, 2006). This feeling of pain inhibition has also been described as a feeling of euphoria.

Endorphins are also directly linked to the consummatory reward complex, which elicits feelings of pleasure, liking and gratification. Increased feelings of inter-personal warmth, euphoria, and bliss have been associated with endogenous opioid release (Comings et al., 1999; Depue & Morrone-Strupinsky, 2005; Koob, 1992; Ferrante, 1996). β -endorphins, along with endomorphins, are some of the most potent endogenous opioid peptides and the analgesic properties of these neuro-transmitters play a paramount role in our ability to manage psychological and physiological stress.

The feeling of temporary satisfaction that occurs due to endorphin release will often stimulate an individual to repeat the previous action in order to achieve the satisfied (fulfilled) sensation. This behaviour has been repeatedly observed in lab rats, as well as in frequent gym goers (Szabo, Griffiths, & Demetrovics, 2013), and in cocaine users (Roth-

Deri et al., 2004). The rewarding nature of social interactions was examined by Krach et al. (2004), who proposed that increased endorphin levels were likely the cause. Evidence from animal studies indicates that the body's internal reward circuit, in the basal ganglia, is part of the pathway tasked with processing rewarding non-social stimuli such as money, food, and psycho-stimulant drugs (Koob & Le Moal, 1997; Schultz, Dayan & Montague, 1997; Izuma, Saito & Sadato, 2008). However, Kelley and Berridge (2002) hypothesized that "the body's underlying neural systems have evolved to facilitate reproductive behavior thus motivating social interactions."

Consequently, the function of the endogenous opioid feedback loop has been associated with multiple activities that have been shown to increase human bonding. Recent research has linked singing (Weinstein et al., 2016), laughing (Dunbar et al., 2012), and group exercise (Sullivan & Rickers, 2013) with increased endorphin levels and increased social bonding. The "Brain Opioid Theory of Social Attachment" (Nelson & Panksepp, 1998), stipulates that "endorphin production suffers during social isolation" and that corresponding chemical responses within the brain can motivate an individual to seek out more social contact in order to promote endorphin production.

Cohen et al. (2010) described the feeling of increased endorphin activity as "a mild opiate "high", with a corresponding feeling of well being, reflecting the role that endorphins play as part of the pain control system". Boecker et al. (2008) confirmed the role of endogenous opioids on the perception of "runner's high" with a group of experienced runners, emphasizing the effect the opioids had on pain perception.

Rickers and Sullivan (2014) referred to endorphins as the neuro-chemical "glue" that, in conjunction with a multitude of other cognitive mechanisms, assist in enabling

humans to develop and maintain their complex social bonds over the course of their life time. “These bonds are created in absence of the hormone-stimulation processes of sex, pregnancy, and birth” (Dunbar et al., 2010), but require these processes for timely neuro-chemical support.

Presently, human endorphin research is lacking in depth. This can be associated to the ethical loopholes and practical difficulties related to the measurement of human opioid levels, as “brain endorphins do not cross the blood-brain barrier, and can only be measured through an invasive lumbar puncture” (Boecker et al., 2008). Recent research has alternatively used non-invasive pain threshold tests as a proxy measure of endorphin activity (Davis et al., 2015; Sullivan et al., 2014; Tarr et al., 2015; Weinstein et al., 2015). The procedure most commonly found in the research literature consists of using a mercury sphygmomanometer (blood pressure cuff), inflated to a pressure where the participant reports discomfort. Similar designs have also used pain threshold tests as a reliable measure of endorphin activity.

2.5 The Synchrony Effect

The synchrony effect is a phenomenon describing the effect of inter-personal synchrony on endorphin levels during vigorous physical activity. The synchrony effect can be defined as “significantly heightened levels of endorphins in individuals after performing an activity in synchronization with a group of people, as opposed to the same activity performed in a non-synchronous manner or alone” (Cohen et al., 2010). Minimal research has been published in this field, as it is reasonably new and relatively unexplored.

Cohen et al. (2010) conducted the seminal research on the synchrony effect. The study investigated the endorphin production of twelve Oxford University rowers while rowing on training ergometers. The participants rowed two sessions, each lasting 45 minutes in duration; the first session was completed in a solo condition and the second was performed while in-phase synchrony with a group. The study used a blood pressure cuff pain threshold test as a non-invasive measure of endorphin levels. The study concluded that vigorous synchronized activity results in a “synchrony effect” whereby pain tolerance, and therefore endorphin activity, was increased. Pain threshold, interpreted as high endorphin levels, increased for participants after both exercise conditions; however the increase was significantly higher following the synchronized condition as opposed to solitary exercise (Cohen et al., 2010). While the exact cause of this endorphin surge remains unknown, it was apparent that there is social aspect to endogenous opioid activation and that the observed heightened effect resulting from synchronized activity had to be related to working together as a coordinated unit.

The synchrony effect was further investigated by Sullivan, Rickers, Gagnon, Gammage, and Peters (2015), who altered Cohen’s original 2010 design to include individuals running on treadmills for 30 minutes in both a solo and group (n=3) trials. Consistent with previous findings Sullivan et al. concluded that the changes in participant’s endorphin levels were significantly higher following the group condition than in the individual setting. Furthermore, Sullivan and Rickers (2013) used the same blood pressure cuff protocol as Cohen et al. (2010), to examine the endorphin levels, pre- and post-exercise, while manipulating the synchrony condition to include both teammates and complete strangers. This study looked to establish whether a synchrony effect could

be produced without any sort of pre-existing social bond amongst the participants. The results concluded that individuals who completed 45 minutes of synchronized ergometer rowing experienced higher endorphin levels regardless of whether they were in synchrony with strangers or teammates. Additionally, Sullivan and Rickers (2014) found that only individuals whose movements were coordinated by in-phase synchrony experienced the synchrony effect.

Harbach et al. (2000) noted that “in addition to the effect that solo vigorous practices have on endorphin activity, vigorous synchronized group activities have an additional effect on the release of endorphins.” While “strenuous behaviours have been noted to produce effects consistent with high opioid levels, including feelings of ecstasy and increased in-group bonding” (Haidt et al., 2008), some studies have cited instances of the synchrony effect independent of vigorous movement. Tarr et al. (2015) recruited high-school students to dance in one of four conditions: high exertion synchrony, high exertion partial synchrony, low exertion synchrony or low exertion partial synchrony. The study found significant positive changes in pain threshold caused by both exertion and synchrony with no interaction effect. Furthermore, Tarr, Launay and Dunbar (2016) concluded that individuals who danced in a synchronous manner experienced significant changes in pain threshold and felt more socially bonded than those who danced in partial or asynchronous conditions. While the vigorousness of the dancing in Tarr’s (2016) study is not noted, it can be hypothesized to be less vigorous than treadmill running or rowing. These findings suggest that the synchrony effect can occur independent of vigorous exercise and that synchrony alone can induce endorphin production. The positive endorphin effects of coordinated group movements are likely why activities such as

dancing, drumming and singing on endorphins have been performed by social groups since the beginning of human existence.

While the current body of research investigating the synchrony effect remains limited, the majority of research concedes positive social outcomes resulting from synchronous movements. The synchrony effect and its role in endorphin release suggest that there is plenty of potential for athletes and other synchronous groups to use the strategy as a means to increase performance potential and suggests that the phenomenon merits significant exploration.

2.6 Group Size and The Synchrony Effect

The majority of research done to date examining social synchrony and the synchrony effect have analyzed small synchronized group efforts. Cohen et al. (2010) examined twelve rowers total, with no more than six individuals working synchronously. Sullivan and his colleagues examined groups as large as six (2013) and two (2014) participants. Davis et al. (2015) examined 20 total participants, but only had the subjects work in synchronized pairs. Tarr et al. (2015) and Tarr et al. (2016) examined groups of three and four respectively in varying protocols analyzing instances of synchronized dancing. Each of the aforementioned studies reported evidence of the synchrony effect, in so far that the observed participants elicited positive social outcomes following synchronized behaviour. Moreover, Weinstein et al. (2016) recruited individuals from a community choir that met in both small groups (n = 20 – 80) and a large ‘megachoir’ group (n = 232). Participants gave self-report measures (via a survey) of social bonding and had pain threshold measurements taken (as a proxy for endorphin release) before and after 90 minutes of harmonized singing. Results concluded increased endorphin levels,

feelings of connectivity and sense of inclusion across singing rehearsals. Additionally similar fluctuations in pain threshold were realized following both small and large group singing. Unexpectedly, levels of social closeness were found to be greater at both pre- and post- measurements for individuals during the small group choir condition. While Weinstein et al. (2016) examined a large group of subjects, the task of singing, requires little movement and minimal physical synchrony. Each of the previous works investigating the synchrony effect, that have found significant results, practiced synchrony through movement rather than auditory cues.

While the literature on the synchrony effect of smaller groups has been well examined, little empirical research has been found that probes the effects of synchronous movements on large groups of individuals during activity. Launay, Tarr and Dunbar (2016) have proposed “that synchrony might act as direct means to encourage group cohesion by causing the release of neurohormones that influence social bonding,” which suggests that synchrony can act as a bonding agent by activating evolutionary neurochemical bonding mechanisms. Launay et al. call for future research to investigate large scale bonding activities to further comprehend the causes and limitations of such occurrences as well as the potential potency of their affects.

Table 1. Studies examining instances of the Synchrony Effect

Study	Sample	Methods	Results and Conclusions
Cohen et al. (2010)	12 Oxford University Rowers	Two trials lasting 45 minutes of continuous rowing on the ergometers. One solo and one synchronized group condition. Pre- and Post- workout pain threshold measured. Likert Scale for motivation and readiness.	No difference in motivation or power output between solo and group conditions. Group trial pain threshold changes significantly elevated above those for individual trials.
Sullivan and Rickers (2012)	24 Amateur Club and University Rowers	Two trials lasting 45 minutes of continuous rowing on the ergometers. One solo and one synchronized group conditions. Group condition consisted of either teammates or strangers (confederates). Pre- and Post- pain tolerance measured.	Individuals displayed significantly higher pain tolerance after vigorous exercise with others compared to solo condition. The observed synchrony effect did not differ between synchronized teammates with teammates or strangers, is therefore independent of prior social bonds.
Sullivan, Rickers and Gammage (2014)	22 Participants with minimum one year of rowing experience.	Three 30 minute ergometer rowing trials. One solo, one in-phase with partner, one anti-phase with partner. Pain threshold measurements taken ~1 min before and after each trial.	Significant pre- to post- changes in pain threshold for each condition. In-phase synchrony condition experienced significantly higher pain threshold than both solitary and anti-phase conditions. No statistically significant differences between genders.
Weinstein et al. (2016)	232 members of a Non-professional choir	Choir members sang in two 90 minute rehearsals one in a large choir (n=232) condition and in sub-choir (n= 20-80) conditions. Pain threshold test performed pre- and post- rehearsal.	The effects of group singing on pain thresholds were found to be comparable, regardless of group size. No significant differences were observed in pain threshold, significant differences were found in feelings of social closeness with larger increases found in the small choir condition.
Tarr et al. (2015)	264 High school students	60 mixed gender groups (n=3) were randomly allocated to one of four movement conditions: high exertion synchrony, high exertion partial synchrony, low exertion synchrony, low exertion partial synchrony. Pain threshold change and self-reported feelings of closeness, connectedness, trust, likability and similarity in personality.	There were significant positive main effects of both exertion and synchrony on change in pain threshold with no interaction effect, as well as a significant main effect of exertion and synchrony independently, on in-group pro-sociality.
Tarr et al. (2016)	94 Participants recruited at Oxford	Test groups consisting of four strangers danced for 13 minutes in one of four conditions (synchrony, partial synchrony or asynchrony). Participants' pain thresholds were measured pre- and post- dancing.	There was a significant main effect of movement condition on change in pain threshold. Those in the synchrony condition experienced a positive significant increase in pain threshold and felt more socially bonded than the asynchronous or partial synchrony conditions.

2.7 Purpose of the Current Study

Synchronous interpersonal movements have repeatedly shown to positively influence sentiments of interpersonal attraction and prosocial behavior (Sullivan et al., 2014). Furthermore, the underlying cause of these occurrences can be attributed to the contemporaneous release of endorphins which have been repeatedly implicated in social bonding (Dunbar & Shultz, 2010, Rickers & Sullivan, 2013). However, one aspect of the synchrony effect that has yet to be explored is the effect of the size of the group participating in the synchronous action. The primary purpose of the current study was to investigate the role of group size on the synchrony effect and to examine how varying group size affected the endorphin activity experienced by the participants. Specifically, rowing under solitary, small group, and large group, synchrony conditions will be investigated for findings similar to those outlined by Cohen et al. (2010), Sullivan and Rickers (2012), and Sullivan et al. (2014). Additionally, no previous literature has been found to date that investigates the endorphin activity, associated with the synchrony effect, after the immediate termination of exercise. The current study looks to take an exploratory approach by conducting extended time sampling measures of endorphin activity at 5 minutes and 10 minutes post exercise.

2.8 Research Hypotheses

The current study aimed to investigate the role of group size on the synchrony effect at multiple time points. Specifically, using rowing in solitary, small group (n=2) , and large group (n=12) conditions, where both group conditions were performed in an in-phase synchronous manner. Each of these trials was evaluated to see if it would produce

the same effect on pain threshold that was seen by Cohen et al. (2010), Sullivan and Rickers (2013), Sullivan & Rickers (2014) and Davis et al. (2015).

Hypothesis #1. Moving in a synchronous manner has repeatedly shown to have a profound effect on people and their corresponding endorphin levels. Furthermore, there is a noticeable endorphin response associated with physical activity. It was therefore predicted that the participants will report increased pain thresholds following each of the 20 minute rowing trials. Due to the vigorous nature of the sport of rowing, the current hypothesis remains consistent with the findings from previous research (Cohen et al., 2010; Sullivan et al., 2012; Sullivan & Rickers, 2013; Sullivan, Rickers & Gammage, 2014).

Hypothesis #2. The literature has reported significant changes in pain threshold following synchronous activity compared to the same activity done in a solitary manner (Cohen et al., 2010; Davis et al., 2015; Sullivan et al., 2012; Sullivan et al., 2014; Tarr et al., 2015). It was therefore predicted that the change in pain threshold following the synchronous conditions would be significantly larger than the change observed following the solitary trial.

Hypothesis #3. Given the findings of Cohen et al. (2010) and Sullivan et al. (2014) that saw significant increases in pain threshold in individuals who completed synchronous exercise, as well as findings from Weinstein et al.'s study (2016) that change in pain threshold was similar following synchronous activity in both small and large group conditions, it was predicted that individuals performing the synchronized activity in both group conditions would experience significant but similar changes in pain threshold than the solo condition.

CHAPTER 3: METHODS

3.0 Participants

Thirty-six rowers, currently training or competing, with the Brock University varsity rowing team or competitive high club teams were invited to participate in the study. Participants were either sweep or scull rowers, and included both lightweight and heavyweight athletes (Table 1). A power analysis using Cohen's d , using an alpha level of ($\alpha=.05$), a beta value of ($\beta=0.2$), and a moderate effect size (0.6), based on two previous investigations (Cohen et al., 2010; Sullivan and Rickers, 2012), was used to calculate a sample size of 35 subjects. Thirty-three (24 Male, 9 Female), completed all three conditions. Participants were required to sign a consent form acknowledging and agreeing to participate in the study. The Brock University Research Ethics Board file number for the current study was 11-062.

3.1 Study Design

The present study combined the methods used by both Cohen et al. (2010) and Sullivan et al. (2012); however, two group size conditions were examined. The subjects participated in a small group condition ($n= 2$) as well as a large group condition ($n= 12$). The size of the large condition was chosen to represent an unfamiliar number of synchronized rowers to avoid any type of familiarity effect that may have occurred in a group of eight, which mimics a group size often practiced in on water training. Unlike Cohen's et al. (2010) original study, where participants rowed as teammates condition in a group of six, or Sullivan, Rickers and Gammage's (2014) study, where participants rowed in partner dyads for both synchronous group

conditions, individuals in the present study rowed in solo, small group, and large group conditions.

3.2 Procedure

Prior to data collection, the study received clearance from the Brock University Ethics Committee. An approval letter granting the collection of data can be found in the Appendix (B). Participants were recruited at Brock University and the St. Catharines Rowing clubs (Appendix A). Coaches and individuals who were interested in participants were asked to contact the research team to confirm their involvement. Individuals who met the inclusion criteria of having rowed for 3 or more years and were currently training injury free, were invited to the University for a testing session. At the first training session, each participant was explained what would be required of them as study participants and were then required to sign a consent form provided by the experimenter. Participants who met the inclusion criteria were also required to complete a PAR-Q form (Canadian Society for Exercise Physiology, 2002), a health status questionnaire used as a screening tool. It was confirmed that each subject was comfortable using a blood pressure cuff as part of the study. Participants who were cleared for activity had their height, weight, age, and rowing experience recorded prior to the first trial (Appendix D). Female participants were also asked to self-report the first day of their last menstrual cycle, for potential corollary analysis between pain threshold changes and specific points during menstruation.

The current study used a counter-balanced repeated measures design. Individuals rowed in three group size conditions: alone, in a small synchronized

group, and in a large synchronized group. In the group conditions, participants rowed in pairs (partner dyads) and large groups containing twelve individuals. Both group conditions were performed using in-phase synchrony, where both rowers moved simultaneously through the movement pattern of the stroke (i.e., both rowers would arrive at the catch and the finish of the rowing stroke together).

The ordering of conditions was counterbalanced to safeguard against any type of learning effect or order effect that may have occurred. One-third of the participants rowed in the solitary condition first, one-third rowed in the small group condition first, and one-third rowed in the large group condition first.

For each trial, the experimenter, along with the research assistants who were blind to the hypothesis but aware of the research question, were on hand at the testing facility. The same researcher assessed the pain threshold of participants for each of the three sessions, with no change of experimenter throughout data acquisition. Participants completed three rowing trials, each consisting of 20-minutes on the stationary ergometer. In the group conditions, participants rowed on parallel ergometers, facing the the same direction. The feet of parallel ergometers were spaced 0.5 meters apart. Sessions were scheduled approximately 3 days apart to avoid fatigue and completed in the afternoon for athlete consistency and to avoid any diurnal effects.

Work done per unit time by the athletes was standardized across conditions by recording the workload over the 20 minute session. Work values were calculated by the ergometer's internal magnetically calibrated flywheel and displayed in Watts (W) by the PM4 monitors. These values were recorded by the experimenter (Appendix E)

during the first session to ensure that participants matched the work intensity in subsequent trials. Participants were asked to row at rate of 26 strokes per minute (spm). This rate closely resembles the rate used in the standardized 6km test, which lasts approximately twenty minutes and is regularly performed by club athletes. Manipulation of the damper setting was used by the experimenters to manipulate the drag factor (resistance) of each ergometer to allow for easier synchronization between participants. This type of manipulation allows an individual, who naturally produces less power than a stronger participant, to maintain the stroke rate required for synchrony with greater ease and fewer adjustments to stroke mechanics. Participants were given the opportunity to perform their own warm ups but were asked to limit their aerobic work to a maximum of five minutes. Additionally 2 minutes were allotted at the end of warm up to allow for practice of synchronization in the large group conditions.

In-phase synchrony required participants to be fully synchronized with one another, whereby each individual remained at identical points throughout the execution of the movement cycle. To accomplish this, participants were required to start at the catch position (top of slide) together and move up and down the slide of the rowing machine simultaneously at the precise stroke rate of 26 strokes per minute. Due to the experience level of the athletes involved and routine training use on the ergometers, participants did not have an issue self-adjusting movements to accommodate in-phase synchrony. In any instances where movements became unsynchronized during any of the rowing sessions, verbal feedback was provided by

the experimenter to allow subjects to adjust their stroke speed to re-establish the correct flow of synchrony.

The blood pressure cuff protocol used in Cohen et al.'s (2010) investigation was performed pre and post exercise trials. Pain threshold measurements were assessed by the research team and recorded approximately one minute prior to the start of each trial and one minute, five minutes and ten minutes following the conclusion of each trial. In each of the three conditions, the same experimenter assessed the pain threshold for each participant. The pain thresholds assessments were performed out of sight from other participants to limit any social interference.

The protocol used consisted of an AMTI medical grade blood pressure cuff being placed above the elbow of the non-dominant arm of the participant being tested. The researcher then manually inflated the cuff to the point of discomfort for participants. When they acknowledged this point during inflation the mercurial pressure on the cuff was then recorded (Appendix E) and the cuff deflated. Millimeters of mercury (mmHg) was used as the measure of pain threshold and was recorded to the nearest 10 mmHg.

Participants rowing in the small group conditions typically completed the trial with partners of the same gender to allow for easier synchronization due to power imbalances. Large group trials consisted of individuals from both genders and from both the varsity and club programs. Subjects were prohibited from taking rest breaks, consuming snacks and listening to music during the training sessions. There was a minimum three day recovery period between sessions for all participants; all sessions

were held in the afternoon or early evening at the Brock University “Leo Leblanc” Varsity Rowing Center.

3.3 Measurements

3.3.1 Rowing Ergometer Test. Twelve Concept2 Model D indoor rowing ergometers outfitted with PM4 monitors, were used for the study. All ergometers were secured and calibrated in the university’s rowing training center. Work done per unit time was used to measure output (watts) and appeared display screen of each ergometer during the workout and can be recorded and recalled after the workout is completed. The tempo of each rower was monitored by the ergometer and displayed as stroke rate. This value was displayed on screen throughout the workout and varied stroke by stroke based on the rower’s movement patterns.

3.3.2 Pain Threshold Test. A pain threshold test using a medical grade Sphygmomanometer (blood pressure cuff) was used to indirectly assess endorphin levels. The current procedure as a non-invasive measure of endorphin activity and has been repeatedly utilized in research investigations (Cohen et al., 2010; Jamner & Leigh, 1999; Zillman, Rockwell, Schweitzer, & Sundar, 1993). Pain threshold measurements were taken immediately prior to and immediately following all three trials.

3.3.3 Physical Activity Readiness Questionnaire (PAR-Q). The PAR-Q (Appendix C) physical readiness questions was implemented in the study for physical activity clearance prior to participation. The questionnaire is comprised of seven “yes” or “no” questions regarding various components of health status. Subjects who answered “no” to all questions were then permitted to completed the vigorous physical activity

associated with the study. Subjects who answered “yes” to any one of the questions were prohibited from participating in the study until they received written permission from their doctor to return to physical activity.

3.4 Statistical Analysis

The Statistical Package for the Social Sciences (SPSS) software, version 20.0 (IBM, Chicago, IL) was used to conduct all statistical analysis. Descriptive statistics, including mean (M) and standard deviation (SD) were calculated for all variables. The dependent variable used for the analysis was change in pain threshold from pre to post score as Dunbar et al. (2012) noted different pain threshold between different individuals. Raw change scores were used in the analyses, as advised by Dimitrov and Rumrill (2003) when investigating physiological measures. A Kolmogorov-Smirnov test found the changes in pain for the solo and group conditions to be normally distributed, but the paired condition was not¹: solo [$F(33) = .367, p < .05$], paired [$F(33) = .039, p < .05$], and group [$F(33) = .328, p < .05$]. Prior to hypothesis testing, the data were examined to see if the assumption of sphericity was upheld. Mauchly’s test was not significant [$W = .907, p > .05$], indicating a homogeneous variance between the conditions. This concludes that the data were appropriate for a repeated measures analysis.

The design of the current study involved collecting data from participants in repeated trials under different conditions (solitary, small group and large group), allowing for a within-group design. A repeated measures analysis of variance

¹ As the paired group was not normally distributed, the data was also analyzed using non-parametric alternatives and similar results were observed.

(ANOVA) was conducted to determine if significant differences existed in the pain threshold change assessed between conditions. Contrast analyses were used to reveal further differences between groups. Supplementary repeated measures analyses were also conducted for pain threshold at five and ten minutes after the exercise session to explore retention of any synchrony effect. At both the five and ten minute time point, the assumptions of normal distribution and sphericity were upheld. Changes in pain threshold between genders was not assessed as Sullivan et al. (2014) were unsuccessful in finding significant differences between genders in pre-activity pain threshold scores or changes scores in any of the examined conditions. An alpha level of $p \leq .05$ was set for all statistical analyses.

CHAPTER 4: RESULTS

Pre- and post- pain threshold scores by condition are shown in Table 1. All three conditions displayed mean increases in pain threshold from pre- to post activity, consistent with the effect of vigorous exercise on endorphin activity described by Boecker et al. (2008). Average pre-test scores did not differ between conditions [$F(2, 72) = 0.65, p = .937$]. Recorded wattage was assessed and did not change significantly for individuals. Pain threshold scores were assessed for differences between genders and no statistically significant differences were found in any of the three conditions: solo [$t = .955, df = 32, p > .05$], paired [$t = .708, df = 32, p > .05$], group [$t = .177, df = 32, p > .05$]. Additionally, there was no significant interaction between group size and change in pain threshold.

Repeated measures analyses were conducted for the change in pain threshold at each time point. The analyses for the immediately post exercise conditions revealed non-significant changes, [$F(2, 32) = 1.90, p > 0.05$], among the three conditions. There were non-significant changes in pain threshold five minutes post-exercise within the three conditions, [$F(2, 32) = .208, p > 0.05$]. However, there were significant differences at the 10 minute post-exercise time point, [$F(2, 32) = 3.65, p < 0.05$] within subject effects. *Post hoc* paired samples t-tests determined that there was a significant difference in pain threshold at the 10 minute post-exercise between the pair ($M=7.27, SD=5.66$) and large group ($M=31.06, SD=7.62$) conditions, $t(32)=-2.79, p < 0.05$. The means and standard deviations of raw pain threshold scores for each condition can be found in Table 1. The means and standard deviations of the changes in pain threshold for each condition can be found in Table 2. Figure 1 depicts

the changes in pain threshold between pair and group trails, over the time points collected in the current research.

Table 2. Means and standard deviations of raw pain threshold scores (measured as cuff pressure in mmHg), by condition.

Condition	Pre Score	Post Score	Post 5 min	Post 10 min
Solitary	213.3 (88.22)	225.3 (105.9)	235.2 (107.7)	231.8 (106.2)
Pair	210.8 (95.9)	232.9 (103.8)	233.6 (102.3)	218.5 (95.8)
Group	212.8 (89.9)	238.8 (102.1)	240.0 (100.3)	244.5 (107.2)

Note. Values are Means \pm 1 SD; number of subjects in each trial = 33.

Table 3. Means and standard deviations of raw pain threshold scores (measured as cuff pressure in mmHg), by condition.

Condition	Pre Score	Δ Post	Δ Post 5	Δ Post 10
Solitary	213.3 (88.2)	11.9 (36.8)	21.8 (36.9)	18.5 (40.6)
Pair	210.8 (95.9)	22.1 (26.2)	22.9 (30.0)	7.7 (32.5)
Group	212.9 (89.9)	25.9 (35.)	27.1 (40.3)	31.1 (43.8)

Note. Values are Means \pm 1 SD; number of subjects in each trial = 33.

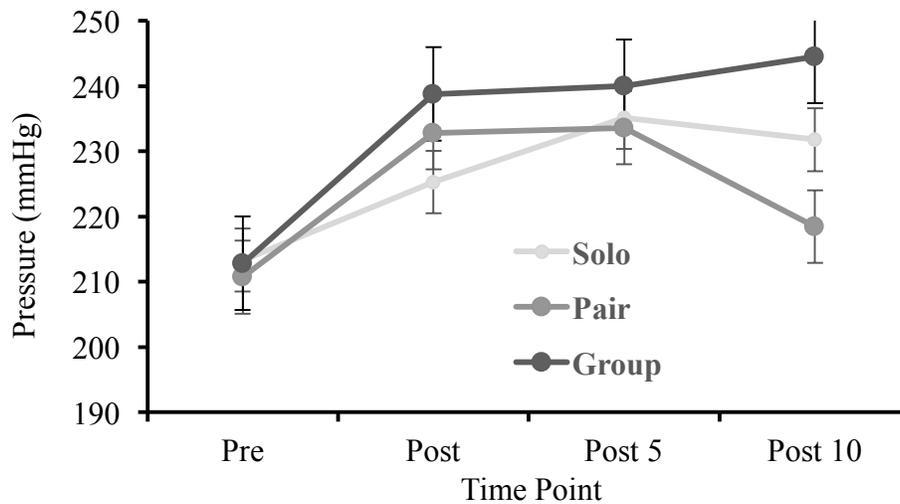


Figure 1. The change in mean pain threshold measured as cuff pressure (in mmHg) for individuals during their solo, pair and group trials. Error bars denote one standard error around the mean. Number of subjects in each trial = 33.

CHAPTER 5: DISCUSSION

5.1 Endorphins and Synchronous Movement

The current study was designed to examine the previously researched “synchrony effect” and to further investigate the correlation between group size (solo, paired or large) and the corresponding changes to pain threshold, used as an indirect measure of endorphin release. Studies to date have only documented the synchrony effect in pairs (Davis et al., 2015; Sullivan & Rickers, 2013; Sullivan et al.) and in small groups (n=3) Tarr et al., (2015), (n=4) Tarr et al. (2016) and (n=6) (Cohen et al., 2010). No previous research has attempted to quantify the magnitude of the synchrony effect in correlation to group size. Additionally, no previous literature appears to have investigated the results of the synchrony effect over time.

Firstly, the current study presents results that mildly conflict with previous research. The present study did not yield the same intensity of synchrony effect as described in previous literature. Each of the previous studies found a significant increase in endorphin activity after either 30 or 45 minutes in synchronous participants. However, the current research was unable to find a significant difference in endorphin activity between solo and group conditions after 20 minutes of rowing. This suggests that 20 minutes of rowing may not be enough to observe a significant increase in endorphin activity, with the current subject pool. It should be noted however that Tarr et al. observed significant changes in pain threshold after just 13 minutes (2015) and 10 minutes (2016) of synchronized dancing respectively. This may have occurred due to the non-constricted nature of dance and the ability of individuals to synchronize multiple limbs simultaneously. In comparison, the rowing

motion is repetitive in nature and restricted to moving in a unilateral manner. Additionally, one of the mechanisms hypothesized to be responsible for the synchrony effect is the occurrence of self-other merging whereby the perception of one's actions can lead to activation of the same neural motor networks involved in making those actions oneself (Fadiga, Fogassi, Pavesi & Rizzolatti, 1995). When our own actions mimic those of another individual's, our intrinsic and extrinsic engagement of neural action-perception networks have difficulty distinguishing between self and perceived others, resulting in a transient bond between the two (Decety & Sommerville, 2003; Marsh et al., 2009; Paladino, Mazzurega, Pavani, & Schubert, 2010; Mazzurega, Pavani, Paladino, & Schubert, 2011).

The synchrony effect has yet to be investigated in a large group condition. To date, only Weinstein et al. (2016) has attempted to examine the effect of group size on the synchrony effect in a singing task, that required no movement and no subsequent significant changes in pain threshold were observed between group sizes. While the literature has examined the synchrony effect in small groups, and supplementary investigations have examined performance in large group scenarios, no empirical research exists that explores the effects of strenuous synchronous movements on large groups of individuals.

To date, there exists a gap in the literature investigating the synchrony effect and its role in endorphin release after the immediate post-movement measurements are taken. None of the previous research has examined the lasting length of the synchrony effect. While each of the studies investigating the synchrony effect have only evaluated the pain thresholds of participants immediately after their assigned

activity (Davis et al., 2015; Sullivan & Rickers, 2013; Sullivan et al., 2014; Tarr et al., 2015; Weinstein, et al., 2016), similar studies have investigated the lasting effects of exercise induced chemical changes on the body. Fuss and Gass (2010) examined runner's high and the consequential short and long term changes in emotional behaviour. Additionally, Kraemer, Blair, Kraemer, & Castracane, (1989), performed extending time sampling from 30 minutes pre to 30 minutes post exercise in an investigation of the effects of treadmill running on beta-endorphin, corticotropin and cortisol levels. The current study is novel as it is the first to collect readings of endorphin levels immediately post-movement as well as five and ten minutes post-completion. The accrued pain threshold data expands our knowledge on the longevity of this phenomenon allowing for unprecedented comprehension of how the synchrony effect influences individuals over an extended period of time after completing synchronous movements.

The results of the extended time sampling clearly outlined a time-based effect interacting with group size. In the large group condition, the synchrony effect was significantly longer lasting and the heightened pain thresholds were maintained for an extended period of time. In Weinstein et al.'s (2016) singing investigation, participants reported significant increases in social bonding but did not experience significantly higher levels of endorphins post performance in the large group condition compared to the small group condition. This is likely due to the lack of movement required during the act of singing as compared to some of the other movements, i.e. rowing, dancing, drumming, that have been investigated. However, some of the same feelings of group affiliation and social closeness may have been

experienced by the current study's participants possibly contributing to their long lasting endorphin surges.

Humans are social beings and support from our peers is essential to human well being. Myers (2000) found that social support is one of the biggest environmental contributors to well-being. This finding suggests a potential for increased well being as a social connections are made with a larger group of people. In the current study, this would be consistent with the long lasting endorphin surge after the large group trial. Furthermore Tajfel (1972) stated that "social groups are not simply external features of the world that provide a setting for our behavior, instead they shape our psychology through their capacity to be internalized and contribute to our sense of self." This notion of group may potentially play a role in the occurrence of the synchrony effect. As individuals are completing their synchronized task, they are psychologically supported by their co-actors. This would allow for greater internal focus of attention, minimization of external distraction, and increased sense of self all while feeling like part of a single entity. The larger the group of co-actors, the greater the psychological support. This increased support could play a fundamental role in the lengthened effect time that was observed in the current research. It should be noted however that the pair trials saw the fastest decrease in pain threshold post exercise. This is likely due to the level of familiarity the participants had with one another and small group training situations. In a large portion of the pair trails participants were rowing with a teammate and this presence may have felt familiar, safe, non-judgmental and could potentially have been cause for social distraction post trial.

The findings of the current study extend our understanding of how the magnitude and the longevity of the synchrony effect is influenced by the quantity of participants in the group. Additionally, it demonstrates that the longevity of the resultant synchrony effect increases with the number of people moving together. The current results remain consistent with previous research done by Cohen et al. (2010), Davis et al. (2015), Rickers and Sullivan (2013, 2014), Tarr et al., (2015, 2016) and corroborates findings that synchronized physical movements elicit an increase in pain threshold, likely affiliated with elevated endorphin activity.

5.2 Implications

The primary implication of the current investigation is that this synchrony effect now appears to be directly influenced by the size of the group involved in the activity. This notion is substantiated by the finding that large group in-phase synchrony produced a longer lasting effect on endorphin release than the small group (pairs) rowing in the same manner. The designs of previous research studies have investigated either pairs trials (Sullivan and Rickers, 2013; 2014) or group trials (Cohen et al., 2010), but none have compared the results from differing group size against each other. Zajonc (1965) postulated that the presence of others serves as a source of arousal which in turn increase the likelihood of an individual to do better in well learned or habitual responses. Cottrell, Wack, Sekerak and Rittle (1968) further developed this hypothesis by stating that performers are only stimulated by an audience capable of evaluating their performance. A study done by Markus (1978) noted that well rehearsed movement tasks, like the sport of rowing, should result in performance increases when in the presence of others. Furthermore Wallace, Baumeister and Vohs (2005) noted that “audience support magnifies performance

pressure and induces performers to avoid failure rather than seek success during critical moments of performance contests, and that supportive audiences can inspire performers to excel when motivation would otherwise be lacking.” It can be assumed for the current study that participants were not influenced by the potential of failure as the ergometer session was in no way competitive however, they may have been stimulated by their co-actors who they equate to potential evaluators. This was likely a contributing factor to the elevated endorphin levels in the large group condition.

Another potential explanation for elevated endorphin levels in the group condition could be due to participant’s heightened sense of self as part of the group and the associated positive sensations. Furthermore, Blascovich, Mendes, Hunter, and Solomon (1999) found that “the presence of others during well-learned tasks produced a “challenge” response, resulting in an increase in cardiovascular activity.” Seeing as though both aerobic and anaerobic exercise stimulate endorphin release (Boecker et al., 2008; Schwarz & Kindermann, 1992) an increase in performance could therefore be responsible for an increase in endorphins as seen by Cohen et al. (2010).

The results of the current study assess a significant gap in the literature and further our understanding of the synchrony effect and support findings that synchronized activity causes an increase in pain threshold. Furthermore, the magnitude of this effect appears to be similar regardless of how many synchronous individuals are moving together; however, in larger groups the results will last longer.

5.3 Limitations

This investigation experienced a number of limitations, however most are likely not restricted to the current study. Firstly, the present study used a sample consisting of elite rowers as subjects to remain consistent with the protocols of Cohen et al. (2010), Sullivan and Rickers (2013) and Sullivan and Rickers (2014). Since the synchronization of the rowing stroke in an in-phase manner with others, requires a specific level of expertise in the sport, a sample size composed of elite collegiate and club rowers was essential. However, another consideration is that these experienced rowers may internally equate synchrony with superior teamwork and that their respective pain thresholds may have been affected. Another limitation surrounding the participants of the current study was the use of young, healthy male and female athletes. A number of questions still exist surrounding whether similar increases in would be evident in changes of pain threshold among “less healthy” or older individuals who may otherwise be unable to complete the tasks required for the current study. Additionally, the current study may have benefitted from collecting participant data on the social effects of each trial. Measure of social closeness and perceived exertion would have allowed for a more in depth comparison between conditions, specifically the pair and large group trials.

Another limitation of the current study, would be the use of 20 minute time trials as opposed to the 45 minute time trials utilized by Cohen et al. (2010) or the 30 minute rowing trials used by Sullivan and Rickers (2014). While the exact duration of time required to initiate the synchrony effect remains unknown, the results in the current study parallel those of Sullivan et al.’s previous work. Additionally, the

synchrony effect has been primarily investigated with individuals participating in the sport of rowing. Rowing in a synchronous manner is ideal for on water performance and thus ideal for team success. Unlike other types of synchronous exercises where group success can occur in an in-phase or anti-phase manner (i.e., figure skating, gymnastics, cycling, running), rowing requires individuals to compete in a in-phase manner in order to achieve success. Sullivan and Rickers (2014) hypothesized that greater increases in pain threshold may have occurred in rowers due to their regular practice of in-phase synchrony and opposition to anti-phase synchrony.

The the use of the blood pressure cuff protocol would be another limitation to the current investigation. Firstly, pain threshold measures were taken as inferences of endorphin activity since “pain is acknowledged to be a subjective experience, for which the gold standard of measurement is self-report” (Hadjistavropoulos et al., 2014). However, perfectly sound results required experimenter and participant consistency throughout all the trials. Secondly, participants they may have become accustomed to their pain threshold being measured via the blood pressure cuff methods and may have simply learned to comfortably withstand more pressure in subsequent training sessions. This may have resulted in the demonstrated “increase” after each bout of exercise. Lastly, a potential for experimenter bias could be realized within the current study design. Without the consistency of an automatically inflated cuff or the use of an experimenter blind to the research hypothesis, the speed and intensity of inflation are subjective. Results of any experiment using this method may therefore become biased due to subtle subconscious changes in the rate of inflation by the experimenter hoping to find the desired response.

The synchrony effect clearly requires further investigation as its mechanism of function and exact causes remain predominantly unknown. Until such exploration occurs, the links between synchrony, endorphins and social cohesion will remain speculative, and we will remain unable to completely harness the synchrony effect to maximize human performance.

5.4 Future Directions

The synchrony effect has been substantiated by a number of different researchers and protocols. It has been repeatedly found that vigorous in-phase synchronized activity causes a significant increase in pain threshold, when compared to asynchronous or solo conditions, which appears to be an indication of heightened endorphin activity. This effect now appears to occur regardless of group size, but will last longer in larger groups of individuals.

As the current study limited participants to experienced rowers, future investigations should look to examine both experienced and non-experienced athletes. Additionally, the present study examined a shorted duration of exercise at the same intensity as previous investigations. Future research should aim to examine a higher degree of training training intensity for shorter periods of time. Lastly, each of the previous studies has examined the synchrony effect in a non-competitive environment. This calls for future investigations examining how people are affected in a similar bout of exercise, but in a competitive environment.

While recent literature supports using a blood pressure pain threshold test as a measure of endorphin levels a more precise measure would be ideal. If an automatic blood pressure cuff could be programmed to inflate until manually stopped by the participant, which would be a more impartial alternative. A direct biochemical

measure of circulating levels of β -endorphin will also provide a better picture of endorphin release.

Further investigation is required to fully comprehend the mechanics and implications of the synchrony effect, explore the the exact role of endorphins as it pertains to pain tolerance increase and determine how its effects can be optimized.

5.5 Conclusions

The phenomenon of people spontaneously and unintentionally synchronizing movements with one another has been observed in multiple different circumstances (Issartel et al., 2007; Richardson et al., 2007; Shockley et al., 2003; van Ulzen et al., 2008). More importantly, synchronization between people can influence their endorphin activity which has been shown to affect their pain threshold (Cohen et al. 2010), cooperation levels (Reddish et al., 2013), and social feelings towards others (Wiltermuth & Heath, 2009).

Dunbar and Shultz (2010) identified endorphins as primary role players in the foundation of social bonding. Using indirect pain threshold measurements, it has been demonstrated that multiple human social bonding activities, such as laughter (Dunbar et al., 2012), singing and dance (Dunbar et al., 2012), and group synchronized sport (Cohen et al., 2010; Davis et al., 2015; Sullivan & Rickers, 2013) are synonymous with elevated endorphin levels. A number of investigations have also indicated higher levels of endorphin release post physical activity when the physical movements being executed were performed in a synchronous manner (Cohen et al., 2010; Sullivan et al., 2014). However, the context of these movements and degree of synchrony to which these actions are performed is paramount. Miles et al. (2009) found two predominant modes of interpersonal coordination, in-phase and anti-phase synchrony.

Sullivan and Rickers (2012) found in-phase synchrony to be the most effective method of synchrony in activating endorphin release.

The present study was designed to investigate if different group sizes would produce different magnitudes of the elevated pain threshold during synchronous activity (Cohen et al., 2010; Sullivan & Rickers, 2013). The current findings demonstrate that the size of the group performing the synchronous exercises does not effect to what degree the effect occurs. Larger group size does however increase the lasting length of the effect. Within the current study, it was found that when individuals rowed in both the pair and large group condition, their pain tolerances increased significantly when compared to the solo trials, but did not differ significantly from one another. Furthermore, when participating in the large group condition, participants demonstrated a significantly longer lasting effect compared to the post-pair trial results. This finding alone may prove to reinforce previous findings within the broader context of synchrony and human social response.

Coordinated movements and behavioural synchrony are commonly part of social and spiritual rituals. They can be fundamental processes that help form the core of one's affiliation, identity, and human expression. Coincidentally, the sensation of social closeness repeatedly observed after synchronized activity, may be responsible for the widespread occurrence of synchronized movements throughout history and may have played an important role in the evolution of human sociality (Dunbar, 2012). Endorphins and their corresponding positive inter-personal feelings have been associated with a number of social behaviors in humans, such as laughter (Dunbar et al., 2011), synchronized sports (Davis et al., 2015), and musical activities like singing

(Wiltermuth & Heath, 2009; Valdesolo & Desteno, 2011) and dancing (Tarr et al., 2015; Tarr et al., 2016). Furthermore, performing these movements in a synchronous manner can magnify the endorphin release caused by exercise itself (Cohen et al., 2010).

Acting in an in-phase synchronous manner has now repeatedly been found to increase pain threshold (Davis et al., 2015; Sullivan & Rickers, 2013; Sullivan et al., 2014). The current investigation supports the findings recorded in the previous literature pertaining to the effect of such synchronous actions on pain threshold, likely as a result of increased endorphins. However it remains unclear how they mediate between shared synchronous movements, positive group affiliation, and pain threshold. In order fully understand the role of endorphins and how they relate to the synchrony effect, further investigation is required. We must come to know if synchrony directly affects endorphins and if so, whether synchrony-induced endorphin activity has the potential to affect physical performance and group interaction. The synchrony effect is an enticing and unexplored area; now is the opportune time to conduct further research on the exact causes and effects of the synchrony effect and how it can be harnessed to optimize human performance and potentially promote reduced pain rehabilitational experiences.

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APPENDICES

Appendix A: Letter of Invitation

The Effect of Group Size on Synchrony and the Synchrony Effect

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INVITATION: You are being invited to participate in a Master's thesis research project examining the effects group size on endorphin production and the synchrony effect.

WHAT WE NEED FROM YOU: Participation in the study requires you to complete a total of THREE 20 minute time trials on a Concept 2 rowing ergometer. Following a time trial in a group condition, athletes' wattage will be recorded and they will be asked to replicate this work load for the subsequent trials. This will allow for effort monitoring across trials. Participants will need to complete one trial in each of the following conditions: solo (alone) condition, small group condition and large group condition. Each of these trials will be completed under the supervision of the researcher. No less than 2 days rest will occur between training days. All sessions will be scheduled through your coach to ensure that the research will not conflict with your practice and competition schedule. Only rowers who are injury free and have completed PAR-Q forms are eligible to participate. Participants will be responsible for their own transportation and parking for all sessions. There will be no cost associated with access to the testing facilities or equipment usage. Details of the training and assessment sessions are as follows:

ASSESSMENTS: All assessments will be supervised by the student research and your program coach. Assessments will take place at the Leo Leblanc Rowing Center, located at Brock University, 1812 Sir Isaac Brock Way, St. Catharines, ON. Prior to the beginning of the study, participants will be required to complete a Physical Activity Readiness Questionnaire and a brief questionnaire to help gather information such as age, rowing experience (years) and whether you prefer to sweep or scull.

All participants will FOUR 20 minute, steady state, continuous rowing ergometer time trials. The assessment sessions will take approximately 40 minutes to complete from start to finish. All training sessions will have a maximum 5:1 ratio of participant to trainer to ensure proper supervision. Current coaches may choose to be present for all assessments. Athletes will be given the opportunity to complete a thorough warm-up prior to any physical testing.

Time Trials: The 20 minute time trials will be performed under THREE different conditions. One condition will see participants completing the time trial alone. Another will see participants completing the time trial in a small group condition. The third condition will see athletes completing the time trial in a large group condition. The tests will be executed at a continuous intensity (must be maintained for 20 minutes) and verbal encouragement will be given by the student researcher as well as coaches and teammates present.

- All data will be collected and archived by student researcher on testing days.

POTENTIAL BENEFITS AND RISKS

Possible benefits of participation include the opportunity complete analysis of the effect group size on the synchrony effect during synchronized rowing trials. Participants will also receive the opportunity to complete multiple time trials at the end of their respective season, not a common practice, which allows for pre and mid season comparison. Potential risks of the physical activity examined in the study include: muscular fatigue, muscular soreness following training, bodily injury to the muscles, ligaments, tendons, and joints, and possible feelings of nausea. Risks specifically associated with high intensity exercise include: occurrences of dizziness, chest pain, fainting, vomiting and cardiac arrest. However, these assessments are consistent with high intensities performed regularly at on water practices or regattas, meaning athletes will have been previously exposed to that similar levels of exertion. The student researcher is certified first aider with the resources available to deal with any minor first aid issue during the assessments. Should a significant injury or illness occur, the participant will be brought to the nearest hospital by parent, coach or ambulance if necessary.

CONFIDENTIALITY

To avoid exposure of personal data and ensure confidentiality of data collection, participants will be completing assessment sessions in an environment where only the coach, student researcher and the athlete being tested have knowledge of results. All data is confidential and only the principal and student researcher will have access. Following publication, electronic copies of data will be distorted to remove participant names and retained for a period of five years. The data will be stored on a research dedicated portable hard drive that is password protected by the principal researcher.

VOLUNTARY PARTICIPATION

Participation in this study is voluntary and not a mandatory team activity. Although athletes will be recruited based on team involvement, participation in the study will be voluntary on an individual basis and each athlete may choose to accept or refuse participation. Athletes who do not wish to participate will suffer no penalty within the team. Should the participant wish to withdraw from this study, they may do so by verbally informing the principal investigator or student investigator, without any penalty. If the participant chooses to withdraw, their data will be destroyed by

deleting any file and shredding any training log related to their participation at the end of the assessment. Data will not be shared or used for further analysis.

PUBLICATION OF RESULTS

A summary of the results of this study will be available and distributed to all participants approximately one month after the final assessment session is completed. This will include a personalized summary with both individual results and a comparison to average group scores. Additionally, scientific results of this study may be published in academic or practitioners journals and/or presented at scientific conferences to advance our knowledge of the effect of group size on the synchrony effect.

CONTACT INFORMATION AND ETHICS CLEARANCE

If you have any questions about this study or require further information, please contact Dr. Phil Sullivan or Zak Lewis using the contact information provided above. This study has been reviewed and received ethical clearance through the Research Ethics Board at Brock University. If you have any comments or concerns about your rights as a research participant, please contact the Research Ethics Office at (905) 688-5550 Ext. 3035, reb@brocku.ca.

If you are interested in participating please complete the attached Informed Consent and submit it to Dr. Phil Sullivan or Zak Lewis using the contact information provided above. Please keep a copy of this form for your records. Thank you for your assistance in this project.

Zak Lewis and Dr. Phil Sullivan

Appendix B: Informed Consent

I agree to participate in the study as described above. I have made this decision based on the information provided through reading this document and assent that:

- I have had the opportunity to receive any additional details.
- I understand that I may ask questions at anytime with regard to the study.
- I understand that I may withdraw this consent at any time during the study.
- I do not have a pacemaker, epilepsy or an abdominal hernia.
- I understand that this is not a team-required activity and I am not obligated as a team member to participate in the study.
- I understand that on and off ice assessments may take place in groups with other participants viewing and encouraging my performance. However, only the researchers and coaches will see my scores.

For Participants and Guardians to complete:

Participant Assent:

In signing this form, I _____
(Participant’s Name) and _____ (Guardian’s
Name) acknowledge that I have received an explanation about the nature of the study
and its purpose.

Parental/Guardian Consent:

I _____ (Guardian’s Name) give my
permission for _____ (Participant’s Name) to participate
in the research as described above conducted by Dr. Phil Sullivan and Zak Lewis.

Photo Permission:

In signing this form, I _____ (Participant’s Name) and
_____ (Guardian’s Name) give permission to for photos and
videos of _____ (Participant’s Name) to be used by Dr.
Phil Sullivan to in presentations of the research (E.g. poster presentation at a
conference).

(NOTE: Photo permission is NOT required to participate.)

Participant’s Name: _____

Participant’s Signature: _____

Guardian’s Name: _____

Guardian’s Signature: _____

Date: _____

Appendix C: Physical Activity Readiness Questionnaire

PAR-Q & YOU

(A questionnaire for People Aged 15-69)

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 your doctor before you start.

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**

YES <input type="checkbox"/>	NO <input type="checkbox"/>	1. Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?
YES <input type="checkbox"/>	NO <input type="checkbox"/>	2. “Do you feel pain in your chest when you do physical activity?”
YES <input type="checkbox"/>	NO <input type="checkbox"/>	3. In the past month, have you had chest pain when you were not doing physical activity?
YES <input type="checkbox"/>	NO <input type="checkbox"/>	4. “Do you lose your balance because of dizziness or do you ever lose consciousness?”
YES <input type="checkbox"/>	NO <input type="checkbox"/>	5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
YES <input type="checkbox"/>	NO <input type="checkbox"/>	6. “Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?”
YES <input type="checkbox"/>	NO <input type="checkbox"/>	7. Do you have a diabetes or thyroid condition?
YES <input type="checkbox"/>	NO <input type="checkbox"/>	8. “Do you know of <u>any other reason</u> why you should not do physical activity?”

If you answered “Yes”:	YES to one or more questions
	A medical clearance form is required of all participants who answer ‘yes’ to any of the eight PAR-Q questions. Note: Personal training staff reserve the right to require medical clearance from any client they feel may be at risk. <ul style="list-style-type: none"> • “Discuss with your personal doctor any conditions that may affect your exercise program.” • “All precautions must be documented on the medical clearance form by your personal doctor.”

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 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 professionals.
Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability to persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME _____

SIGNATURE _____

DATE _____

SIGNATURE OF PARENT _____

WITNESS _____

or GUARDIAN (for participants under the age of majority)

"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."



Supported by:  Health Canada Santé Canada
Physical Activity Readiness Questionnaire - PAR-Q

(revised 2006 by CW)

Appendix D: Athlete Information Form

Descriptive Rower Information:

Name: _____

School/Club: _____

Highest Level of Competition: _____

Age: _____ **Primarily Train Sweep/Scull:** _____

Height: _____ **Weight:** _____

Years of rowing experience: _____

Start Date of Last Menstrual Cycle (if applicable): _____

Appendix E: Subject Ergometer Test Data

Name:				
Solo Condition				
Trial Date:				
Work (W)	Pre-Threshold	Post-Threshold	5min Post Threshold	10min Post Threshold
Pair Condition				
Trial Date:				
Work (W)	Pre-Threshold	Post-Threshold	5min Post Threshold	10min Post Threshold
Group Condition				
Trial Date:				
Work (W)	Pre-Threshold	Post-Threshold	5min Post Threshold	10min Post Threshold