The effect of different phases of synchrony on the synchrony effect

Katelyn Rickers, RN, B.Sc.N, B.Sc.Ed

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Under the supervision of Philip J. Sullivan, PhD

Faculty of Applied Health Sciences, Brock University

St. Catharines, ON.

ABSTRACT

Synchronization of behaviour between individuals has been found to result in a variety of prosocial outcomes. The role of endorphins in vigorous synchronous activities (Cohen, Ejsmond-Frey, Knight, & Dunbar, 2010) may underlie these effects as endorphins have been implicated in social bonding (Dunbar & Shultz, 2010). Although research on synchronous behaviour has noted that there are two dominant phases of synchrony: in-phase and anti-phase (Marsh, Richardson, Baron, & Schmidt, 2006), research on the effect of synchrony on endorphins has only incorporated in-phase synchrony. The current study examined whether both phases of synchrony would generate the synchrony effect. Twenty-two participants rowed under three counterbalanced conditions - alone, in-phase synchrony and anti-phase synchrony. Endorphin release, as measured via pain threshold, was assessed before and after each session. Change in pain threshold during the in-phase synchrony session was significantly higher than either of the other two conditions. These results suggest that the synchrony effect may be specific to just in-phase synchrony, and that social presence is not a viable explanation for the effect of synchrony on pain threshold

Keywords: behavioural synchrony, endorphins, pain threshold, in-phase synchrony

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CHAPTER ONE: LITERATURE REVIEW

1.1 Social Interaction

Connecting with others is the root of human sociality (Miles, Nind, Henderson, & Macrae, 2010). This simple, yet significant coordination fact has been examined repeatedly by social psychologists observing interactional synchrony, the evolving and unintentional coordination found in natural social interactions (Davis, 1982).

Social links can be established by a variety of routes; however, one intriguing pathway focuses on the physical movements that occur during social interaction. Simply put, the degree to which individuals' movements are alike can influence how they feel about each other. An extensive amount of literature supports this observation and demonstrates that in coordinating individual actions with others through either imitation (Chartrand & Bargh, 1999; Macrae, Duffy, Miles & Lawrence, 2008; van Baaren, Janssen, Chartrand, & Dijksterhuis, 2009) or synchronization (Sebanz, Bekkering & Knoblich, 2006; Miles, Nind & Macrae, 2009; Wiltermuth & Heath, 2009; Valdesolo, Ouyang & DeSteno, 2010), positive social outcomes (liking, rapport, cooperation) can be attained.

As a working definition, synchrony refers to the degree of congruence between the behavioral cycles of two or more people (Bernieri & Rosenthal, 1991). Comparably, Sebanz and colleagues (2006) regard synchrony as being joint action "whereby two or more individuals coordinate their actions in space and time to bring about a change in the environment" (p. 73). In recent years, investigating perception and action in a social context has made major advances (Sebanz et al., 2006). Research on joint attention, task sharing, action coordination, and synchrony contribute to the understanding of the cognitive and neural processes supporting coordinated movements. Research also suggests that synchrony operates by bolstering feelings of solidarity, therefore increasing prosocial behaviours (Lumsden, Miles, & Macrae, 2014).

Behavioral synchrony is believed to be a basic component of human social interaction, serving as a foundation for successful social exchange (Marsh, Richardson & Schmidt, 2009; Sebanz et al., 2006; Semin & Cacioppo 2008). The attraction to coordinate with other individuals is fundamental, serving as the basis for our social connectedness to others (Marsh et al., 2009). In this regard, behavioral synchrony provides one possibility through which these interpersonal links can be formed.

Primatologists and animal behaviourists have suggested that synchronized action is a vital skill for animals; it facilitates learning, enables collective responses to danger, and strengthens alliances among packs (Connor, Smolker, & Bejder, 2006). Likewise, anthropologists and sociologists have speculated that cultural practices such as music, dance and marching have endowed some groups an advantage in societal evolution. Armies, churches, and community organizations, have for centuries, engaged in activities that lead group members to act in synchrony with each other (Wiltermuth & Heath, 2009). Soldiers train by marching in step, religions worldwide incorporate synchronous singing and chanting in their rituals, and sports teams practice drills and warm-ups in a coordinated manner. Group coordination establishes a basis for social cohesion among any and every group that keeps together in time, moving large muscles together and singing, shouting or dancing rhythmically.

“Muscular bonding” is the term given for this phenomenon (McNeil, 1997), as it is related to the euphoric feeling that is experienced following rhythmic muscular movement. Additionally, a growing body of evidence displays that individuals moving together in time serves as a co-operation-enhancing mechanism -“social glue” (Dunbar et al., 2011; Marsh et al., 2009; Valdesolo, et al., 2010).

Recent research has shown that people are inclined to coordinate their movements with others in a variety of tasks including rocking in rocking chairs (Richardson, Marsh, Isenhower, Goodman, & Schmidt, 2007), hand waving (Macrae et al., 2008), drumming (Kirschner & Tomasello, 2009) and walking on a treadmill (van Ulzen, Lamoth, Daffertshofer, Semin, & Beek, 2008). Synchronization of actions and goals is an important phenomenon in successful social interactions between humans; these interactions have been studied in both intentional and unintentional scenarios (Richardson et al., 2007). It has been observed in coordination tasks requiring mutual information exchange between individuals, as well as scenarios of unintentional scenerios whereby one individual aligns with another through mimicking or simulation (Macrae et al., 2008).

Presumably, the attraction to such a coordinated state tells us something about the connectedness of a pair. For instance, previous research on mimicry and observed synchrony suggests that mimicry and synchrony are associated with greater rapport between pairs and foster cooperation (Chartrand & Jefferis, 2003). It has also been speculated that the role of joint action is so influential that in certain pair-bonded animals, failure to coordinate behavior may lead to physical isolation, thereby increasing risk for predation or reduced hunting capacity (Dunbar & Shultz, 2010). A similar process has been considered in human evolution, as individuals who were more disposed to social synchrony were more likely to experience meaningful social benefits, increasing probabilities of reproduction and therefore carrying on these social tendencies (Haidt, Seder, & Kesebir, 2008)

1.2. Consequences of Synchrony

Moving together appears to have a profound effect on people; people tend to be inclined to move synchronously, whether to external stimuli or to partners. This phenomenon is linked to the evolutionary importance of synchronized movement in humans and other species. Within the past decade, several academics have demonstrated that synchronized movement increases rapport, liking and pro-social behavior. Evidence for a causal link has been provided by Hove and Risen (2009). In their study, participants (all female) performed a tapping task next to another person, synchronizing their finger movement with a visual or auditory signal. Each of the two individuals responded to separate signals so that the target tempo for their tapping could be more or less similar. Even though participants knew that the signals determined to which extent they and their task partner were synchronized, those who had been more in sync with their partner subsequently reported liking her more.

Synchrony also seems to boost people's willingness to cooperate with group members (Wiltermuth & Heath, 2009). In a coordination game, participants who had walked in step in groups of three made more cooperative choices than participants who had not walked in step. Those who had engaged in synchronized walking also reported feeling more connected and trusting each other more. The same was true for groups of three singing in synchrony. Of specific interest was the further finding, using multiple rounds of a public-goods game, that following synchronous group actions, the level of participants' contributions to the public good did not significantly fall as time went by, whereas the level of such contributions did decline over time in groups that had not engaged in synchronous behavior. Furthermore, it was found that non-physical coordinated actions showed the same effect on group cooperation that physical activities did. Subjects who sang together showed significantly greater post-activity cooperation than did subjects who sang alone (Wiltermuth & Heath, 2009). In particular, synchronized activities, whether vigorous or not, resulted in individuals having enhanced perceptions of team identity. These findings suggest that not only does synchrony facilitate increased cooperation on tasks, but also that individuals engaging in synchronous actions gain and increased sense of joint identity, or of being united on the same team.

Put simply, whether people spontaneously act in coordination with each other, or one person mimics the actions of another, there appears to be a robust effect on such actions on interpersonal attraction and pro-social behaviour. Thus, synchrony leads individuals to believe that their counterparts functioning in unison are increasingly similar to themselves in terms of personal attributes (Valdesolo, Ouyang & DeSteno, 2010). Taken together, these findings on the consequences of synchrony suggest that synchrony may function as an implicit marker of similarity by leading individuals to perceive themselves as having a joint identity, or of being united.

1.2.1 In-phase and Anti-phase Synchrony. Experimental research has revealed the association between behavioral coordination and enhanced social connections (Semin, 2007; Semin & Cacioppo, 2008). However, research has also demonstrated that interpersonal synchrony is characterized by two specific modes of coordination: in-phase and anti-phase (Haken, Kelso, & Bunz, 1985; Schmidt, Carello, & Turvey, 1990). In-phase coordination would be apparent when two individuals are in performing a task while moving simultaneously together in time. As such, the actions of each individual would be at equivalent points of the movement cycle at the same time. In contrast, anti-phase coordination would display the reverse pattern, whereby each individual's actions would be at opposite points of the movement cycle at the same time.

Synchrony has been mathematically demonstrated in terms of the Haken–Kelso–Bunz (HKB) equation which reveals that when the oscillations of independent instruments are paired, they will, by way of mutual influence, spontaneously settle at one of two stable attractor states: in-phase or anti-phase (Haken et al., 1985). Importantly, Haken and colleagues (1985) state that synchrony at all levels (i.e., packs of animals, mechanical metronomes, crowds of people, sport and exercise) is ruled by similar self-organizing physical principles.

The degree of coordination, specifically its stability, may influence fundamental aspects of social exchange (Miles, Henderson, & Macrae, 2009). Stability refers to the robustness of the coordination mode to disruption or perturbation (Miles, Nind, Henderson & Macrae, 2010). For example, when instructed to synchronize oscillatory leg movements, paired partners could only maintain stability in an in-phase and anti-phase mode of synchrony (Schmidt, Carello, & Turvey, 1990). The same results were found when dyads swung hand-held pendulums and without being instructed, spontaneously coordinated movements in an only in-phase or anti-phase mode (Schmidt & O'Brien, 1997).

As such, it has been suggested that stable interpersonal synchrony creates a "mooring effect" (Marsh et al., 2009) or a union, thereby enhancing the experience of connectedness between interacting individuals (Macrae et al., 2008). Consequently, while in-phase and anti-phase are both considered stable modes of coordination, it is the in-phase type of synchronization that represents an overall attractor state (Haken et al., 1985).

1.3 Mechanisms of Synchrony

In-phase and anti-phase coordination may serve distinct social functions. For instance, to successful propel a boat down the river, a rowing crew must coordinate in an in-phase manner by performing their strokes in unison. Conversely, a successful conversation depends on turn taking between speakers in anti-phase coordination, creating a synchronous dialogue (Miles, Nind, Henderson, & Macrae, 2010). It has been suggested that stable coordination may influence fundamental aspects of social exchange. For example, steady coordination has been associated with enhanced rapport (Miles, Nind, & Macrae, 2009) and liking for interaction partners (Hove & Risen, 2009). In addition, Macrae, Duffy, Miles, and Lawrence (2008) demonstrated that memory for an interaction partner's appearance and utterances were enhanced following in-phase, compared to anti-phase coordination.

Furthermore, Miles et al. (2009) demonstrated that people evaluate the connectedness of individuals in a dyad based on the perceived synchrony of their movements. Participants saw or heard footsteps of pairs of walkers walking in a more or less synchronized manner and rated their degree of rapport. The results showed that participants attributed the highest levels of rapport to those pairs of walkers that displayed in-phase or anti- phase coordination, and assigned the lowest levels of rapport to walkers displaying phase relationships that were far from in-phase or anti-phase. Therefore, it can be inferred that the most stable patterns of synchrony were clearly perceived as reflecting a close connection between individuals, regardless of whether information about the walkers' synchrony was conveyed through visual or auditory information.

Synchronization capacities in a social environment were explored through spontaneous sensorimotor synchronization in young children (Kirschner & Tomasello, 2010). It was established that joint music making (drumming) enhanced prosocial behavior in 4-year-old children. Three groups of children, all under five years of age, were invited to beat a drum along with a human partner (social condition), a drumming machine (audio-visual condition), or music emanating from a speaker (acoustic condition). The researchers observed that for all age groups, drumming with a social partner was synchronized with the highest accuracy; they maintained that motivation amongst the children to synchronize movements was due to a perceived shared representation of the joint action task. The information and research presented by Kirschner and Tomasello (2010) shed light on the unique impulse we have as human beings to share actions and experiences with others through acts of synchrony.

Miles et al., (2009) examined whether intentionally synchronizing or avoiding synchronizing movements with a partner influenced self and social perceptions of others. Participants were told they would be exploring online interactions by interacting with another participant via video-link. Participants were required not to communicate with one another but to simply concentrate on forming a sincere impression of the other participant. Participants were also required to perform arm curls while holding a metal rod throughout the 90-second interaction. In order to control coordination, participants were asked to either intentionally synchronize or avoid synchronizing their arm curl movements. Results indicated that the coordination condition had a significant impact on how participants viewed themselves, as well as how they viewed their relationship with a partner. Individuals had higher self-esteem following intentional synchronous movement with the video-link partner compared to non-synchronous movement. Thus, it appears that moving in synchrony with others may result in individuals feeling better about themselves compared to when moving to one's own rhythm.

1.3.1 Cognitive Outcomes. Synchrony may have cognitive benefits as well. These benefits have been connected to research on the mimicry of discrete bodily movements and the coordination of more continuous sequences of action (Semin & Cacioppo, 2008). Thus, engaging in joint action might facilitate jointly recruited processes, which permit access to others' states. Moreover, being connected socially should be felt not only in terms of liking and feeling of "group-ness", but also more generalized feelings of harmony and flow, which may aid in memory storage or retrieval processes (Macrae et al., 2008).

Whereas previous research on this topic has focused primarily on social cognitive outcomes that tap perceptions of rapport, Macrae, Duffy, Miles, and Lawrence (2008) demonstrated how coordinated action might modulate the gaining of knowledge during a dyadic interaction, by manipulating the manner in which an experimenter's hand movements were synchronized with the actions of participants. The movements of some participants directly mirrored the experimenter's actions (representing "in-phase" synchrony); for other participants, their actions were synchronized but phase shifted to an opposing manner (representing "anti-phase" synchrony). For a final group of participants, behavioral synchrony was not established ("no-movement" control). Their results showed that memory for core aspects of a brief social exchange were facilitated following movements had been performed in coordination together. Specifically, when the hand movements of the participants and experimenter were synchronized and the in-phase form of synchrony, both memory for the words and facial appearance was enhanced. Interestingly, there were no benefits associated with anti-phase synchrony; memory performance in the anti-phase and control conditions was equivalent. This finding is noteworthy as anti-phase synchrony is also a stable state to which people are pulled (Marsh, Richardson, Baron, & Schmidt, 2006). Thus, one would perhaps have expected anti-phase participants to outperform their counterparts in the control condition.

With that being said, it appears that beyond the general connection between behavioral coordination and positive social outcomes, the type of the coordination itself has significant impact on both social interaction and cognition.

1.3.2 Social Outcomes. The social implications of joint-actions have been documented following both the mimicry of discrete bodily movements and the coordination of more continuous sequences of action. Put simply, people tend to react favorably to those that mimic their actions. For example, through the research of the effects of arbitrary group membership on the appearance of interpersonal coordination, Miles, Griffiths, Richarson, and Macrae (2010) studied female participants' performance of repetitive arm curls to the beat of a metronome. They were first tested individually, and then while viewing another participant performing the same task via video screen. Subjects wore a coloured sticker (red or blue), which identified them as being a member of an group. Both groups displayed stable in-phase coordination with their confederate. However, participants who were told that group membership had relevance showed differences in coordination as a function of such membership. Interestingly, these participants showed more synchronous movement with members of the opposite group (those wearing a different coloured sticker) than compared to the participants in their own group identity (those wearing the same coloured sticker). This seems counterintuitive, and appears to contradict the bulk of research demonstrating a tendency toward maintaining psychological distance from dissimilar others. However, these results suggest that interpersonal coordination may act as a medium to support the reduction in intergroup differences and diminish social distance. The researchers summarized that the coordination dynamics governing interpersonal synchrony are flexible and able to accommodate social influences, even in the absence of any explicit requirement to do so.

Improvements in joint action performance following synchronous movements, as well as gains in understanding due to synchrony during conversation provide further demonstrations of the benefits of synchrony.

Support for the powerful influence of synchrony on perceptual and motor ability adds to the escalating literature on the social function of coordinated movement in several significant ways. In a study by Valdesolo, Ouyang, and DeSteno (2010), two groups of participants rocked in rocking chairs. One group rocked next to each other, which allowed them to synchronize, while the other group rocked back to back to avoid synchronization. In the synchronous group, participant pairs sat in rocking chairs placed side by side, and were instructed to rock in time together; in the asynchrony group, pairs sat back to back to minimize the possibility of unintentional synchrony. After rocking for 90 seconds, participants completed perceptual sensitivity tasks and joint-action tasks. As predicted, participants who had rocked in synchrony were subsequently better at an individually performed perceptual sensitivity task that required judging the speed of an occluded object, compared to participants who had rocked back to back. The researchers suggested that, as in the case of military and athletic warm-up drills, synchrony might not only bring people together, but allow them to practice the very skills essential to achieving their goals. These findings support the view that in addition to fostering social cohesion, synchrony hones the abilities that allow individuals to functionally direct their cooperative motives. These findings also provide a first indication that synchrony may have effects on the quality of subsequent joint action performance.

Recent research has established in laboratory settings that such coordinated activities can influence inter-individual cooperation and social bonding. In a series of studies, Wiltermuth and Heath (2009) found that coordination in different group activities was positively related to cooperation. In their first study, participants walked around campus in one of two randomly assigned conditions, either marching in step in groups of three, or in groups of three in their normal gait. In post marching activities, participants who marched in step showed significantly greater cooperative behavior than those who walked alone. Subsequent studies replicated this effect when using a variety of activities. In particular, it was found that non-physical coordinated actions showed the same effect on group cooperation that physical activities did. Subjects who sang together showed significantly greater post-activity cooperation than did subjects who sang alone. It was also found that synchronized activities, whether vigorous or not, resulted in individuals having enhanced perceptions of team identity.

These enhanced feelings of team bonding may be due to a chemical effect associated with these coordinated activities. It has been suggested that these rhythmic group activities lead to higher endorphin activity compared to the same activity performed alone. Endorphins are known to result in a feeling of well-being, which could be implicated in increased cooperative behavior.

1.4 Endorphins and group-based social behaviours

Recent research may have unveiled a potential mechanism for the social effects of synchrony. It appears that synchronous behaviours, particularly vigorous synchronous behaviours, elevate participants' endorphin levels, which have been linked to social bonding in both non-primate mamammls as well as primates (and hence humans) (Dunbar, 2010; Dunbar & Shultz, 2010; Machin & Dunbar, in press). Endorphins are a class of endogenous opioid peptides produced in the central nervous system (CNS) that not only function as neurotransmitters but also play a crucial role in the management of pain through their analgesic properties. In particular, β-endorphin appears to have a central function in buffering against the effects of physiological and psychological stress within an individual (Dunbar et al. 2011). β-endorphins are the most potent endogenous opioid peptide; they have been implicated in the regulation of physical and emotional stress and pain, as well as the reward of social interaction (Machin & Dunbar, in press).

Endorphins are linked to fulfillment and reward, which elicits feelings of pleasure, liking and satisfaction, thereby motivating the individual to seek out the rewarding behaviour. Social contact may result in the release of endorphins, resulting in the above feelings. Inquiries by Machin and Dunbar (in press) suggest that endorphins' effect in the social realm has evolved due to a unsophisticated role in the body's pain and reward systems, whereby pain of social isolation and the reward of social contact exist. Their research suggests that while non-primate mammals may use endorphins to maintain infant-maternal and partner bonds, primates may be much more dependent on the endorphin system to maintain complex, varied and continuing social networks.

In primates, the bonding process has a distinctive emotional component in the form of the pharmacological pleasure associated with the release of endorphins (Keverne et al., 1989). One unique aspect of primate social behaviour is the extent of their social networks and, in humans, the need to maintain these social networks. This requires an alternative behavioural mechanism (i.e. endorphins) for the maintenance of social bonds (Dunbar, 2008; 2010). It has been suggested that endogenous endorphins may mediate between affiliative stimuli (e.g., shared synchronous movements) and affiliation (DePue & Morrone-Strupinsky (2005). For example, Dunbar and Shultz (2012) concluded that social grooming in primates builds strong social bonds through the release of endorphins, "which provides a psycho-pharmacological mechanism that enables two individuals to build a bonded relationship with some kind of deep emotional basis" (p.782).

In humans, the role for the endogenous opioids system has been implicated in a range of behaviours that may aid in bonding human groups on a larger scale. Recent research has suggested three possible mechanisms: music, laughter and group-based exercise, including dance forms, all of which may be linked to the release of endorphins.

Psychologically, endorphin release is experienced as a mild opiate "high"; a corresponding feeling of well being, reflecting the role that endorphins play as part of the pain control system (Cohen et al., 2009). For example, positron emission tomography (PET) scanning has recently confirmed a role for endogenous opioids in the phenomenon of the "runner's high" – the post-exercise euphoric state experienced by runners (Boecker et al., 2008). Furthermore, Dunbar et al. (2011) examined the physical action of laughing that generates positive affect by triggering activation of the endorphin system. In a series of group experiments, participants were exposed to one of two social conditions: the experimental group (watching a comedy video) and the control group (watching a documentary). Given that humans do not laugh readily when observing even the funniest shows alone and laughter is 30 times more likely to occur in social contexts than when alone, all subjects were tested in groups (Dunbar et al., 2011). Pain threshold was measured using a frozen vacuum wine cooler sleeve as well as a mercurial sphygmomanometer (blood pressure cuff). Results of the study determined that condition had a significant effect with change in pain threshold being significantly elevated in the experimental (comedy) condition compared to the control (documentary) condition.

Endorphins might be the neurochemical "glue" that, in conjunction with other cognitive mechanisms, enables both human and non-human species to maintain their complex social bonds over extended periods of time. These bonds are created independently of the hormone-stimulation processes of sex, pregnancy and, birth (Dunbar et al., 2010). Additionally, referring to the Brain Opioid Theory of Social Attachment (Nelson & Panksepp, 1998), social isolation results in low levels of endorphin production, motivating an individual to find or seek out social contact. Therefore, social contact fittingly results in the release of endorphins, providing feelings of euphoria, contentment and reward (Machin & Dunbar, in press).

1.5 The Synchrony Effect

The synchrony effect (SE) is a newly established phenomenon referring to the discovery that interpersonal coordination in vigorous physical activities affects endorphin levels. As a working definition, the SE can be defined as individuals showing significantly heightened levels of endorphins after performing a vigorous activity in synchronization with a group of people, as opposed to the same activity performed alone (Cohen, Ejsmond-Frey, Knight, & Dunbar, 2010). This is a particularly new and unexplored field of study, therefore, little empirical research exists to date. Nonetheless, if endorphins produce a sense of well being, and fulfillment, it may be that through synchronized activity, social bonding processes (cooperation, motivation, rapport) are enhanced (Lakin, Jefferis, Cheung, & Chartrand, 2003).

The role of vigorous exercise in a group condition on endorphin production is provided by Cohen and colleagues (2010) who examined the rowing performance of 12 elite athletes, all of whom were teammates on the same university rowing team. Each participant rowed on an ergometer in both individual and group conditions; both sessions were 45 minutes long. Participants were instructed to row at a maintainable pace and workload in terms of 500 m split time was monitored and standardized between conditions. A blood pressure cuff pain threshold test was used as a measure of endorphin levels. Past literature acknowledges this procedure as the most non-invasive measure of central endorphin activity as brain endorphins do not cross the blood-brain barrier and can only be measured through an invasive lumbar puncture (Boecker et al. 2009; Cohen et al. 2010; Dearman & Francis 1983; Jamner & Leigh 1999; Zillman et al. 1993). Similar designs have used pain threshold as a valid measure of endorphin levels (Dunbar et al., 2011).

Cohen et al. (2010) concluded that vigorous synchronized activity results in a "synchrony effect" whereby endorphin activity is increased. It was found that pain threshold (interpreted as high endorphin levels) increased in both conditions but that this increase was significantly higher (almost double) following group as opposed to solitary exercise, indicating a social aspect to endogenous opioid activation (Cohen et al., 2010). However, whether this enhanced opioid activation leads individuals to be more prosocial and altruistic towards fellow group members remains to be seen. Although exact features of group activity that generated this endorphin surge remain unknown, it was apparent that this heightened effect from synchronized activity in a group condition was in some way related to the effect of working together as a highly coordinated team. Furthermore, while the sample size was small, their link between synchrony and endorphin activity in a group setting may have helped to explain the sense of euphoria experienced during other social activities that are involved in social bonding in humans.

To support the generalizability and validity of the synchrony effect, Sullivan, Rickers, Gagnon, Gammage, and Peters (2011) followed the design of Cohen et al. (2009) and extended the basic protocol by using groups of three running on treadmills for 30 minutes as compared to six rowers rowing for 45 minutes. Consistent with Cohen et al.'s original study, it was found that individuals' post exercise endorphin levels (as measured via a pain threshold test) was significantly higher in the group than individual setting.

Although the outcomes of both studies suggested that the synchrony effect might be a replicable finding, there was one characteristic of the original design that characterized a confounding factor with the synchrony condition. In Cohen et al.'s study, the participants were all members of the same rowing team. Thus, it was important to establish if the synchrony effect is independent of the presence of individuals to which the participant may already have a social bond.

As a result, the synchrony effect was replicated by Sullivan and Rickers (2012) who once again used the same protocol as Cohen et al. (2010) and Sullivan et al. (2011), with participants who were strangers as well as rowing teammates. Because of the role of endorphins in social bonding, the study investigated whether the use of teammates in Cohen's study may have influenced results. Sullivan and Rickers found that when individuals rowed for 45 minutes with either teammates or strangers, they still displayed significantly higher changes in pain threshold than when they rowed alone.

In general, it appears that vigorous synchronized group activities have a noticeable effect on the release of endorphins. This result would be in addition to the effect of vigorous activities alone on endorphin activity (Harbach et al, 2000). The effect of coordinated group movements on endorphins is consistent with the role of such behaviors in many social groups. Actions such as dancing and drumming have traditionally been noted to have effects consistent with high opioid levels, including feelings of ecstasy and increased in-group bonding (Haidt et al., 2008). Furthermore, social activities in primates have been linked to increased endorphin levels (Keverne, Martensz, & Tuitem, 1989). Perhaps these types of activities also result in a significant release of endorphins amongst participants, and as these individuals experience the associated sense of wellbeing that endorphins cause (Stefano et al., 2000) in an intense social context, they experience enhanced social bonding.

With respect to grooming and infant attachment, both research and evidence from non-primate mammals for the involvement of the endorphins in prosocial behaviour is widespread. Conversely, that from humans is noticeably lacking in robustness. This is likely due to the ethical and practical difficulties associated with the measurement of opioid levels from humans as brain endorphins do not cross the blood-brain barrier and can only be measured through an invasive lumbar puncture (Boecker et al. 2009; Cohen et al. 2010; Jamner & Leigh 1999; Zillman et al. 1993).

Literature written within the past few years validates using a blood pressure pain threshold test as a measure of endorphin level. This procedure is the most non-invasive assay for central endorphin activity. Comparable designs have used pain threshold as a valid measure of endorphin levels. For instance, Panksepp (1999) argued that laughter is an engagement system which signals an individual's readiness to play, an invitation for continued social contact that is often expressed in the group context where it acts as a bonding mechanism. This suggestion has recently gained support from a collection of studies, which assess the impact of laughter upon the ability to tolerate pain. In one series of studies subjects who watched video or live comedy performances experienced elevated pain thresholds compared to controls who watched neutral or unexciting shows (Dunbar et al., submitted). A similar phenomenon may be at play when considering the impact of music upon human affective states and affiliation. There is also indication that private experience of music increases blood plasma endorphin levels and induces euphoric states (Blood & Zatorre, 2001; Stefano et al., 2004). However, music may also be a mechanism by which group level bonds can be maintained via the medium of performance. For instance, a study found that members of a capoeira dance group had elevated pain thresholds following their dance class compared to less physically active classes (Kaskatis, 2006; Machin & Dunbar, 2011).

While attention should be noted in respect of all these findings due to small sample sizes and the use of pain threshold as a representation for endorphin release, overall they suggest that endorphins may be implicated in group level social bonding in humans. Such a process would be coherent with the results of Wiltermuth and Heath (2010). Although they did not measure endorphin activity directly, the authors did find that coordinated activities resulted in greater in-group cooperation. Considering the synchrony effect, this cooperation may have been due to an endorphin-induced euphoria in the participants.

Interestingly, Wiltermuth and Heath (2010) also found increased cooperation after non-vigorous activities, opening up the possibility that the synchrony effect may also occur following less strenuous coordinated tasks. Whereas vigorous activities such as running and rowing have equivalences in such social activities as dance and marching, less vigorous coordinated actions, such as tai chi or drumming, have also been implicated in social bonding. Consequently, perhaps the synchrony effect is due to the coordination of the activity regardless of how physically demanding it is. The literature reveals that in-phase and anti-phase are the most stable means of interpersonal synchrony. However, one aspect of synchrony that may be relevant to the synchrony effect is the phase of synchrony; the degree of coordination required to produce the synchrony effect. There are two dominant phases of synchrony - in-phase and anti-phase (Marsh, Richardson, Baron, & Schmidt, 2006). Humans appear to prefer in-phase synchrony (Marsh et al., 2006; Richardson et al., 2007). Furthermore, in-phase synchrony appears to have a more powerful effect on some of the outcomes noted above (Macrae, Duffy, Miles, &

Lawrence, 2008). Although these two different phases may both have an effect on the outcomes of synchronized behaviours, to date, the synchrony effect has only been investigated with in-phase synchrony.

Current research on the synchrony effect phenomenon remains limited. Most literature acknowledges pro-social behavior as an outcome of synchronous movements; however, a lesser amount of experimental research surrounds the notion of endorphin activation. Nonetheless, the role of endorphins in relation to group based movements and social bonding appears to be a potentially robust area warranting further investigation.

CHAPTER TWO: RATIONALE, PURPOSE, & RESEARCH PREDICTIONS

2.1 Rationale

The possibility exists that coordinated action not only facilitates the motivation to pursue joint goals with others, but also elicits a heightened endorphin release. The potential role that endorphin release plays in this relationship is intriguing. In addition to promoting higher pain threshold (Dunbar et al., 2011) endorphins are known to cause feelings of well-being and social bonding (Cohen et al., 2009). The role of endorphins suggests that more vigorous coordinated activities may produce a more powerful synchrony effect.

The degree of synchrony required to produce the synchrony effect remains unexplored. Though research on synchronous behaviour has established that there are two dominant phases of synchrony -- in-phase and anti-phase synchrony (Marsh, Richardson, Baron, & Schmidt, 2006), to date, research on the effect of synchronous movements on endorphin release has only incorporated the in-phase form of synchrony.

Current findings by Miles et al. (2009) on in-phase and anti-phase synchrony demonstrate that the manner in which behavior is coordinated is an important determinant of the perception of interpersonal connectedness and levels of rapport. This is consistent with research stating that in-phase and anti-phase coordination reflect the generally stable attractor states for interpersonal coordination (Schmidt et al., 1990; Schmidt & O'Brien, 1997). Although these two different phases may both affect outcomes of synchronous behaviour, to date, only the synchrony effect, relative to in-phase synchrony has been examined. Therefore, it was important to develop a research study that examined whether both phases of synchrony would generate the synchrony effect.

As previously stated, there has been no study to date which has examined the synchrony effect using features that specifically test the mechanism through which endorphin release is heightened. Studies to date have only examined in-phase synchrony to test for elevated endorphin levels; anti-phase synchrony remains an unexplored area. Thus, the phase of synchrony to which this heightened endorphin release is experienced warrants further investigation. Results of this study may have implications for a wide variety of social behaviors, such as memory, cooperation, coordination, rapport and cohesion. By further clarifying the nature of the synchrony effect, our hope is to offer a more complete understanding of cohesiveness in small groups and improve individual affect and social cooperation in various contexts.

2.2 Purpose

As previously established in Chapter 1, there appears to be a robust effect of synchronous actions on interpersonal attraction and prosocial behavior (Cohen et al., 2010). Additionally, a noticeable effect on the release of endorphins has been shown which may underlie these effects, as endorphins have been implicated in social bonding (Dunbar & Shultz, 2010, Rickers & Sullivan, 2013). However, one aspect of synchrony that may be relevant to the synchrony effect is the phase of synchrony required to produce the synchrony effect. Marsh et al. (2006) state that there are two dominant phases of synchrony -- in-phase and anti-phase. Therefore, it is possible that divergent phases of behavioural synchrony may have different effects on the synchrony effect.

Thus, the overall purpose of the current study was to investigate the role of different phases of behavioral synchrony on the synchrony effect and to distinctly examine the phase of synchrony required to produce the synchrony effect. Specifically, rowing under solitary, in-phase and anti-phase synchrony conditions were examined to see if all would produce the same effect on pain threshold that was seen by Cohen et al. (2010) and Sullivan and Rickers (2012). The present study combined the methods used by both Cohen et al. (2009) and Sullivan et al. (2012); however, two social conditions existed. The sample participated in one synchronous (in-phase) condition; they also performed the exercise in an opposite movement (anti-phase) condition. Unlike in Cohen's et al. (2009) original study where participants rowed in a teammate condition as a group of six, this study required participants to row in partner dyads for both synchronous group conditions.

2.3 Research Predictions

The current study investigated the role of different phases of synchrony on the synchrony effect. Specifically, rowing under solitary, in-phase and anti-phase synchronous conditions were studied to see if all would produce the same effect on pain threshold that was seen by Cohen et al. (2010) and Sullivan and Rickers (2013).

The following research predictions were forwarded as a result of the previously stated purpose and rationale for the present study.

2.3.1 Research Prediction #1. Moving in coordination with others appears to have a profound effect on individuals. Furthermore, it appears that vigorous synchronized physical activities have a noticeable effect on the release of endorphins. Therefore, it was predicted that individuals would show pain threshold differences from pre to post exercise across all social conditions. Specifically, significantly higher pain thresholds would be displayed post-vigorous exercise. This is consistent with findings from previous research (Cohen et al., 2009l Sullivan et al., 2011).

2.3.2 Research Prediction #2. Because previous research has noted significantly greater increases in pain threshold after synchronous activity compared to solitary activity, extending on the hypothesis from research question #1, it was also predicted that there would be a significant difference among the three conditions. Based on previous research (Cohen et al., 2010; Sullivan et al., 2011), it was predicted that change in pain threshold after activity performed in a synchronous condition would be significantly greater than pain threshold after the activity performed in a solitary condition.

While both in-phase and anti-phase synchrony provide stable modes of interpersonal coordination (Haken, Kelso, & Bunz, 1985), in-phase synchrony serves as a stronger attractor state (Marsh et al., 2006). However, anti-phase synchrony has not yet been studied with respect to the synchrony effect, thus, no specific hypothesis was put forward regarding this condition.

CHAPTER THREE: METHODOLOGY

3.1 Participants

A total of twenty-two individuals (9 male, 13 female) volunteered to participate in the study. All were recruited from the university and local rowing club. At the time of recruitment, all students rowing on the varsity rowing team were invited to join the study; local rowing club members were recruited after receiving responses from varsity rowing team members. As such, 18 out of 22 (81.8%) participants were composed of varsity rowers; 4 out of 22 (18.2%) participants where were composed of local rowing club members. Individuals belonging to the varsity rowing team rowed together. Likewise, members of the local rowing team all performed trials together. As such, varsity level rowers and club level rowers never completed trials together. Participants ranged in age from 19 to 55 years old (*M* = 31.14, *SD* = 13.13). The average height for male participants was 73.11 inches (*SD* = 1.54) and weight was 200.56 pounds (*SD* = 23.91). The average height for female participants was 67.62 inches (*SD* = 1.94) and weight was 145.00 pounds (*SD* = 12.75). Inclusion criteria required all participants to have a minimum of one year of competitive rowing experience as well as previous indoor training on a rowing machine. In-phase and anti-phase synchrony required specific level of expertise in the sport. Therefore, using individuals who were proficient in the sport offered more precision within each training condition.

3.2 Phase-locking. In the experimental conditions, participants were explicitly required to coordinate rhythmic movements and "lock" into one of two phases: in-phase or anti-phase. Stroke rate was capped at 24 strokes per minute. By holding a constant stroke rate, this enabled participants to "lock" into the two social synchronous conditions and move up and down the ergometer slide at an even pace, and thus, synchronizing movements together in an in-phase or anti-phase manner. If the participants lost coordination at any time point throughout the 30-minute trial, the experimenter cued participants back into either in-phase or anti-phase synchrony by providing verbal feedback.

3.3 Design Analysis

This study involved collecting data from the same participants under repeated conditions (solitary and group sessions/in-phase and anti-phase conditions), which made for a within-group design. Thus, individual differences were reduced as a source of between group differences. All assumptions of ANOVA (normal distribution, independent samples, equal variances) were checked prior to data analysis. The independent variable measured was condition (alone, in-phase and anti-phase). To determine if there was a statistically significant difference between pain thresholds within the three conditions, a repeated measured ANOVA was conducted. Contrast analyses revealed further differences.

3.4 Materials

3.4.1 Physical Activity Readiness Questionnaire (PAR-Q). The PAR-Q was implemented for physical activity clearance prior to participation. It was comprised of seven "yes" or "no" questions regarding health status. Participants who responded "no" to all questions were permitted to engage in vigorous physical activity. Participants who answered "yes" were not able to partake in training sessions until permission from their doctor to be physically active was obtained.

3.4.2 Concept2 Rowing Ergometer. Twelve Concept2 Model D indoor rowing machines (a.k.a "ergometers") were set up in the rowing center of the university. Power output was measured using a 500m average split time; the time taken to row approximately 500m on the rowing machine. This measurement was shown on the display screen of each ergometer. The pace of each rower was monitored using a stroke rate. Once again, this was shown on the display screen of each rowing machine.

3.4.3 Sphygmomanometer (blood pressure cuff). As in Cohen et al.'s (2009) original study, a blood pressure cuff pain threshold test was used as an assay of endorphin levels. Given that brain endorphins do not cross the blood-brain barrier, this procedure was used as an non-invasive, valid measure of endorphin activity (Cohen et al., 2010; Jamner & Lee, 1999; Zillman, Rockwell, Schweitzer, & Sundar, 1993). Measurements were taken immediately proceeding and following both trials. The blood pressure cuff was placed above the elbow of the participant's non-dominant arm. Ischemic pain was induced through manual inflation of the blood pressure cuff to increase compression. Participants indicated the point at which the pressure became uncomfortable by saying "now". The pressure was then recorded and the cuff was removed from the arm. Units of pressure were documented in mmHg.

3.4.4 Camera. Each participant was filmed during his or her group sessions. Upon completion of these sessions, experimenters reviewed the video footage to ensure synchronization of movements by both partners during the in-phase and anti-phase trials.

3.4.5 Anthropometric Measures. Height, age and weight were not fundamental components in this study. However, they were acquired from each participant. Height (in feet), weight (in pounds) and age (in years) were acquired from each participant through self-report measures.

3.5 Procedures

Prior to data collection, this study attained clearance from ethics at the institution. An approval letter granting data collection can be found in the appendix. Participants were recruited at Brock University and throughout the Niagara Region. Individuals who expressed interest were asked to contact the research team to confirm their involvement. Individuals who met inclusion criteria were invited to the university for a testing session. Upon the first training session, each participant signed a consent form provided by the experimenter. Participants also completed a PAR-Q form (PAR-Q; Canadian Society for Exercise Physiology, 2002), a self-screening health status questionnaire which required required each individual to answer to using “yes” or “no” responses. Those who replied with “yes” to any of the questions were required to obtain doctors permission before taking part in physically activity. Those who answered “no” to all questions were cleared to participate in the study. All participants were able to partake in the testing sessions.

The experiment used a counterbalanced repeated measures design. Individuals rowed in three conditions - alone, and in two synchronized group conditions. In the group conditions, participants rowed in pairs (partner dyads) and in two synchronous conditions: in-phase and anti-phase. In the in-phase synchrony condition, both rowers kept in the same movement pattern (i.e., rowers were both in the fully extended and fully contracted position of the stroke at the same time). In the anti-phase synchrony condition, rowers kept at the opposite points of the movement pattern (i.e., when one rower was in the fully extended position, the other rower was in a fully contracted position, and vice versa). The ordering of conditions was counterbalanced so that one-third of the participants rowed alone first, one-third rowed in the in-phase synchrony condition first, and the remaining one-third rowed in the anti-phase synchrony condition first. This was done to safeguard against any type of learning effect or order effect that may have occurred.

Across trials, the experimenter was present in the training facility. Participants underwent testing by the same researcher each session with no change of experimenter through data acquisition. Participants were required to complete three trials; all consisted of 30-minute ergometer training session. Sessions were scheduled approximately one week apart.

Workload intensity (i.e., wattage) was standardized across conditions by recording the 500-m split time (i.e., the time taken to row 500m on the ergometer machine) over the 30 minute session. Values were recorded during the first session and participants matched the intensity in subsequent trials. Participants were asked to row at rate of 24 strokes per minute (spm). A good target stroke rate for most workouts is in the range of 24–30 spm (Concept2, 2013). By slight manipulation of a damper setting, the experimenters were able to control the drag factor of each ergometer and establish synchrony between participants while allowing individuals to maintain the same intensity (i.e., wattage) in all three conditions. Participants were given approximately five minutes to warm up before being instructed to row at a workload (power output) they were comfortable sustaining for the 30-minute duration. The pace was recorded to ensure participants maintained an equal pace in the subsequent trials.

In-phase synchrony required participants to be fully synchronized with one another. That is, a zero degree relative phase relationship, whereby the actions of each individual were at equivalent points of the movement cycle. To accomplish this, both individuals mimicked one another; this involved moving up and down on the slide of the rowing machine together at the precise stroke rate of 24 strokes per minute together simultaneously.

Anti-phase synchrony is an 180-degree relative phase relationship to in-phase synchrony, whereby individual actions are at opposite points of the movement cycle. This required one participant to be at the beginning of the rowing motion or “catch” position, while the other participant was at the end of the rowing motion or “finish” position. Thus, one individual was at the front of the track on the rowing machine while their partner was at the back of the track on rowing machine. Due to the experience level and routine training use on the ergometers, most participants found the task of self-adjusting movements to an in-phase or anti-phase form of synchrony very easy to attain. If movements became unsynchronized at any time point throughout the session, verbal feedback was provided by the experimenter and quickly adjusted by participants by shortening or lengthening strokes to attain the proper phase of synchrony once again.

Measures of pain threshold were taken before and after all trials using the blood pressure cuff protocol used by Cohen et al. (2010). All pain measurements were taken by the experimenter and recorded approximately one minute prior to the start and conclusion of each trial. In all conditions, the same experimenter assessed pain threshold for all participants. This was achieved by staggering the end of workouts of participants by approximately 30 seconds each. The pain thresholds of all participants were assessed away from all others being tested. The blood pressure cuff was placed on the elbow of the non-dominant arm of each participant. Pressure was gradually increased through the manual inflation of the cuff to induce ischemic pain. When the pressure became uncomfortable, participants were instructed to say “now”. At this time, the pressure was recorded and the cuff removed. Pain threshold was recorded to nearest 10mmHg.

Participants rowed with the partners in both in-phase and anti-phase synchronous conditions; pairs typically consisted of rowers of the same gender. Varsity rowers completed trials with other varsity rowers. Rowing club members competed trials with other members of the club. All participants were prohibited from listening to music or consuming sports drinks during their training sessions. There was a weeklong gap between sessions for all participants; all sessions were held in the afternoon or early evening.

CHAPTER FOUR: RESULTS

4.1 Data Analysis

After the study was completed, all recorded data was entered into the quantitative data analysis software program Statistical Package for the Social Sciences (SPSS) version 17.0. Prior to data analysis, data was screened for entry errors, missing data and to check the parametric assumptions of the statistical tests. A data set was created and further analysis was carried out in a series of phases.

4.1.1 Screening Data. Before any statistical analyses occurred, frequency tables were inspected to uncover missing data in all independent and dependent variables. Data that was entered into SPSS software was inspected for data entry errors. In total, twenty-four individuals participated in the experiment. However, two participants did not complete their individual ergometer session. Therefore, these participants' results were eliminated from data entry.

4.1.2 Screening for Assumptions of Data Analyses. Pain threshold differs by individual (Dunbar et al., 2012), therefore, change in pain threshold from pre to post exercise was used as the dependent variable in the analysis process. Although using raw change scores in this type of analysis poses numerous questions, research has shown that when using reliable scores, particularly physiological measures, it is appropriate to use raw change scores (Dimitrov & Rumrill, 2003). Change in pain threshold from pre to post exercise across all three conditions (alone, in-phase, anti-phase) was examined. Average pre-scores did not differ between conditions all three conditions displayed mean increases in pain threshold from pre to post activity, a result consistent with the effect of vigorous exercise on endorphin activity (Boecker et al., 2008). Furthermore, there was no statistically significant difference between genders in pre activity pain threshold scores or changes in scores in any of the three conditions.

All data was further examined to ensure that parametric assumptions of repeated measures ANOVA were met. Based on Field's (2009) discussion of statistical procedures, three major parametric assumptions were tested. They included: interval data, normally distributed data and the assumption of sphericity.

4.2. Interval Data. The assumption of interval data assumes that equal intervals on the scale represent equal differences in the property being measured (Field, 2009, p.133). An interval scale was used to assess pain threshold, the continuous variable used in this experiment. In the context, pain threshold scores for every participant were measured at equal intervals on a measurement scale via blood pressure cuff measured in millimeters of mercury (mmHg). Though the gauge of the blood pressure cuff began and 0mmHg and went to 350mmHg, actual participant scores ranged from 150-350 mmHg.

Table 1

Means and Standard Deviations of Raw and Change Pain Scores by Condition

Condition	Pre-activity *M, (SD)*	Post-activity *M, (SD)*	Change score *M, (SD)*
Alone	178.64 (38.95)	210.00 (51.73)	31.36 (29.96)
In-phase	196.82 (55.41)	247.73 (50.89)	50.91 (28.60)
Anti-phase	194.55 (51.89)	224.09 (52.34)	29.55 (29.52)

Note. Pain threshold was measured in mmHg. Normal distribution for change scores exists in all three conditions ($F_{(2,63)} = 0.89$, $p < .05$).

4.2.1 Normal Distribution. Change in pain threshold was normally distributed in all three conditions; all three conditions displayed mean increases in pain threshold from pre to post activity, which is uniform with the effect of vigorous exercise on endorphin activity (Boecker et al., 2008). Table 1 depicts the change in pain threshold and normally distributed data from pre to post exercise within all three conditions.

Field (2009) writes that to accurately check that the distribution of scores is approximately normal, the values of skewness and kurtosis must be analyzed. Skewness depicts the level of symmetry of the distribution. Normally distributed data is symmetrical, thus giving a skewness of zero. For each condition, the skewness score was converted to a z-score by dividing by the standard error to determine the amount of actual skewness within each condition. Field (2009) acknowledges that if the resulting score is greater than 1.96, there is statistical significance. All conditions had skewness scores less than 1.96 resulting in non-significant results (p <0.05).

The same process was followed to determine the level of kurtosis within each condition. Kurtosis refers to the degree to which scores cluster at the ends of the distribution (Field, 2009); in other words, the sharpness of the peak of a distribution curve. The kurtosis value for each independent variable was converted into a z-score by dividing by the standard error to determine the amount of actual kurtosis within each condition. All results were less than 1.96 indicating normal distribution.

According to Field (2009), another statistical method to test whether the distribution as a whole deviates from a comparable normal distribution is the Kolmogorov-Smirnov test. Results gave a significance of 0.20 within each condition and thus were not statistically significant (*p*<.05). This confirmed that the distribution of the sample was not significantly different from a normal distribution.

4.2.2 Sphericity. Due to the repeated measures design of this study, data was examined to see if the assumption of sphericity was upheld. Field (2009) articulates that sphericity is a more general condition of compound symmetry and refers to the equality of variances of the differences between conditions or treatment levels. (p.459). To measure sphericity, Mauchly's test of significance was performed which tests the hypothesis that there is equality amongst the variances of the differences between (Field, 2009, p.460). Results were non-significant (*p*>0.05*)*, indicating homogeneous variance between the conditions (conditions were approximately equal). Thus, the condition of sphericity was met and data was appropriate for a repeated measures analysis.

4.3 Assessing Wattage. To ensure power remained consistent throughout the experiment, participants were asked to maintain a "wattage" they could hold for the duration of the 30 minute trial (in all three conditions). Wattage is measured by the 500m split time on the ergometer machine and is an indicator of power output by each individual pulling. Results showed that wattage did not change significantly across conditions for individuals. Thus, participants average power output was roughly equal across conditions.

4.4 Testing Research Predictions

Pain threshold differs by individual (Dunbar et al., 2012), therefore, change in pain threshold from pre to post score was used as the dependent variable in analyses. A small amount of concern surrounds using raw changes scores in such analyses, however research has shown that when using reliable scores, particularly physiological measures, using raw change scores is warranted (Dimitrov & Rumrill, 2003) Therefore, pre and post pain threshold scores by condition were used and can be seen in Table 1.

4.4.1 Research Prediction #1. It was predicted that differences in pain threshold would be evidenced amongst participants from pre to post exercise across all three conditions. A repeated measures analysis of variance (ANOVA) results showed a statistically significant difference ($F_{(1,65)} = 98.5$, $p < .001$, $\eta^2 = .602$); all three conditions displayed mean increases in pain threshold from pre to post exercise. Specifically, the pre to post exercise pain threshold was significantly different in each separate condition (the alone condition, in phase condition and anti-phase condition). This is a result that is consistent with the effect of vigorous activity on endorphin release as cited by previous research (Boecker et al., 2008; Cohen et al., 2010) and reported in the original studies done on the synchrony effect (Cohen et al., 2010; Sullivan & Rickers, 2013). There were no statistically significant differences between genders in pre-activity pain threshold scores or change scores in any of the three conditions.

Observed power within the design was 0.70. Following the main analysis, contrast analyses were carried out, which compared the independent variable to examine where a difference existed.

4.4.2 *Research Prediction* #2. It was predicted that there would be a significant difference between the three conditions. An ANOVA showed that the three conditions were unequal; a significant effect for condition was produced with an effect size ($F_{(2,42)} = 4.12$, $p < .05$, $\eta^2 = .16$). Using the scales of magnitude given by Cohen, Miles and Shevlin

(2001) for partial eta-squared for factorial ANOVA, small = 0.02; medium = 0.13; large = 0.26. Therefore, the result indicated a medium-large effect size.

Planned comparisons looked at the effect of one independent variable at individual levels of other independent variable. Bonferroni adjusted contrast analyses revealed that the in-phase synchronous condition was significantly different from both the solitary ($F_{(1, 21)} = 5.27$, $p < .05$, $\eta^2 = .20$) and anti-phase conditions ($F_{(1, 21)} = 8.99$, $p < .01$, $\eta^2 = .30$). The partial eta-squared for the in-phase synchronous compared to solitary condition was of large size. Likewise, the partial eta-squared for the in-phase synchronous compared to anti-phase synchronous condition was again of large size. Interestingly, contrast analyses revealed no significant difference between the solitary and anti phase conditions ($F_{(1, 21)} = 0.41$, $p > .05$).

Figure 1 summarizes these comparisons by illustrating the mean change scores for pain threshold across all three conditions. The in-phase synchronous condition represents the condition with the most significant increase in mean pain threshold (M = 50.91).

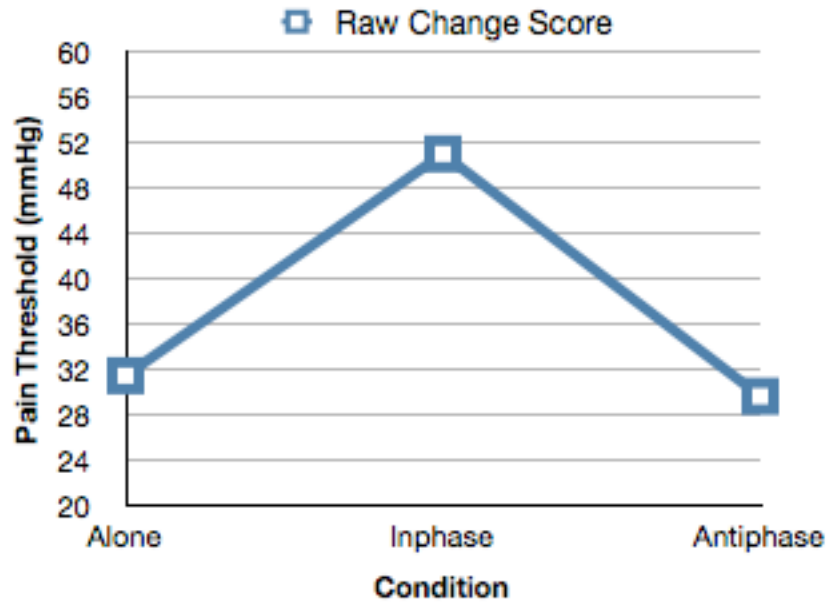

Figure 1. Results of Mean Change Pain Scores Across Three Conditions.

CHAPTER FIVE: DISCUSSION

5.1 Synchronous Movements, Social Bonding and Endorphins

The current study was designed to examine the previously researched "synchrony effect" and to furthermore investigate whether two different phases of synchrony (in-phase and anti-phase) would both produce heightened endorphin release as measured by elevated pain threshold. Studies to date have only documented this increased pain threshold with in-phase synchrony (Cohen et al., 2010; Sullivan & Rickers, 2013).

The results were revealing. The study showed that when individuals rowed vigorously in an in-phase synchronous condition, they produced significantly heightened levels in pain threshold from pre to post activity compared to both solitary and anti-phase synchronous rowing conditions. Results also showed no statistically significant difference between rowing in a solitary or anti-phase condition, thus, demonstrating that the synchrony effect appears to be only a result of an in-phase synchronous condition (whereby coordination of movements together are at equivalent points of the movement cycle) and produce a heighten endorphin surge far superior to that seen in an anti-synchronous condition (whereby each individual's actions are at opposite points of the movement cycle) or solitary setting.

It has repeatedly been found that individuals have a significantly elevated pain threshold after vigorous activity done in synchrony with others compared to after the same vigorous activity carried out alone (Cohen et al., 2010; Sullivan and Rickers, 2013). This has been found with varying samples, including teammates and strangers, and both males and females. Whereas Cohen et al.'s (2010) original research only involved male rowers who were teammates, Sullivan and Rickers (2013) incorporated strangers and teammates and males as well as females, and the current study also found the effect using both sexes as participants. Thus, the synchrony effect may serve as a mechanism for this increased cohesion through the release of endorphins.

The current research extends our knowledge on the synchrony effect by confirming that synchronized movements done in an in-phase synchronous manner, the form of synchronized movements preferred by people (Marsh et al., 2006; Richardson et al., 2007) cause an even greater endorphin release than compared to the same synchronized movements done in an anti-phase synchronous manner. To date, the synchrony effect has only been investigated in in-phase synchronous conditions. The original research on the synchrony effect by Cohen et al. (2009) used only an in-phase synchronous condition with teammates. Sullivan and Rickers (2013) replicated the synchrony effect by using the same protocol but including both teammates and strangers, Once again, their study only used an in-phase synchronous condition. Literature notes in-phase and anti-phase synchrony as being the two dominant phases of interpersonal coordination (Haken et al., 1985; Chartrand & Bargh, 1999). Humans appear to prefer in-phase synchrony; it appears to have a more powerful effect on prosocial outcomes and more notably, endorphin outcomes (Macrae, Duffy, Miles & Lawrence, 2008; Marsh et al., 2006; Richardson et al., 2007). Therefore, the current study is novel in that it is the first to incorporate a second condition using anti-phase synchrony. Furthermore, the inclusion of an anti-phase synchronous condition expands on our knowledge on this phenomenon; it determines that the synchrony effect now may be independent of any social facilitation effect, a result established through the finding that the in-phase synchronous condition produced a more pronounced effect on endorphin release compared to anti-phase synchronous condition.

At this point, it appears that the synchrony effect is a robust phenomenon. Findings of the present study extend our understanding of the results produced by the synchrony effect. Furthermore, it remains consistent with previous research done by Cohen et al. (2009) and Rickers and Sullivan (2013) and validates findings that vigorous synchronized exercises causes an increase in pain threshold, which appears to be an indicator of elevated endorphin activity.

5.2 Implications

The main implication of this current research is that this synchrony effect now appears to be independent of any social facilitation effect. This was established through the finding that in-phase synchrony produces an effect on endorphin release whereas anti-phase synchrony does not. The designs of both Cohen et al. (2010) and Sullivan and Rickers (2013) included a confounding factor - the synchronous condition was the only group condition. Tasks rooted in physical performance, like the sport of rowing, should result in performance increases when in the presence of others (Strauss, 2002). The research done by Cohen et al. (2010) and Rickers and Sullivan (2013) had consistency in performance in both conditions, however it may be that other responses were affected. The presence of others has been known to have an effect on unlearned responses, particularly when looking at cardiovascular activity. A study performed by 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 exercise stimulates endorphin release (Boeker et al., 2008) a change in performance could be responsible for the change in endorphins as seen by Cohen et al. (2010). Therefore, it may have been possible that the endorphin effect that Cohen attributed to synchrony was actually a mere presence effect. However, in the context of this present study, the synchrony effect was not produced when a second synchronous group was introduced (i.e. anti-phase synchrony). Less significant changes in endorphin release, interpreted via pain threshold, were seen in the anti-phase synchronous condition when compared to both the in-phase synchronous condition and alone condition. With this in mind, it appears that the effect on endorphins is due to synchrony, in particular in-phase synchrony, rather than any social facilitation effect.

Another potential implication of the current study may be the possibility that through synchronous in-phase movements, endorphin release is heightened and therefore promotes prosocial behaviours (DePue & Morrone-Strupinsky, 2005; Dunbar & Schultz, 2010). In the case of vigorous synchronous activities like rowing, this endorphin release is above and beyond what is induced by exercise itself (Cohen et al., 2010). Furthermore, it may be that synchronized movements done in in-phase synchrony, the form of synchronized movements preferred by people (Marsh et al., 2006; Richardson et al., 2007) causes an even greater endorphin release. In addition to increased pain threshold, it has been established that other effects of endorphins are increased memory, attention, cooperation, rapport and feeling of connectedness (Dunbar & Shultz, 2010; Kirschner & Tomasello, 2009; Macrae et al., 2008; Valdesolo et al., 2010, Wiltermuth & Heath, 2010). Therefore, it is possible that shared synchrony would result in greater cohesion and stronger social ties among participants, thus showing that through the synchrony effect, vigorous synchronized activity releases endorphins, which results in increases in social bonding. This series of actions would be consistent with the theory that collective activities increase cohesion among group members in activities such as marching in step and rhythmic dancing and singing during religious activities (McNeil, 1995). Thus, the synchrony effect may serve as a mechanism for this increased cohesion through the spurring of endorphins.

The present results further our understanding of the synchrony effect and support the finding that vigorous synchronized activity causes an increase in pain threshold, which appears to be indicative of elevated endorphin activity. Furthermore, this effect now appears to be the result of synchrony; specifically in-phase synchrony, as opposed to social co-action.

5.3 Limitations

There are several shortcomings to the current design, which are probably not restricted to the current study. One of the major limitations to the present study is the sample used to obtain data. In following the protocol of Cohen et al.'s (2010) and Sullivan and Rickers (2013) studies, the current sample was composed of experienced collegiate and club level rowers; inclusion criteria required all participants to have a minimum of one year of competitive rowing experience as well as previous indoor training on a rowing machine. In-phase and anti-phase synchrony required specific level of expertise in the sport. Therefore, using individuals who were proficient in the sport offered more precision within each training condition. However, it is plausible that these experienced rowers may equate synchrony with superior teamwork and that the consequent pain threshold may have been effected. Likewise, the synchrony effect may not generalize to those participants not experienced with the task of rowing.

Secondly, all of the participants were healthy male and female athletes. Inquiries exist surrounding whether the same increase in pain threshold would be evident among "less healthy" individuals who perhaps lack the aerobic base and athleticism that was required by participants in both the original research investigation by Cohen et al. (2010) as well as this current study.

The duration of time spent at each training session on the ergometer rowing incorporates another limitation to this study. Cohen et al. (2010) had athletes complete 45 minutes of continuous rowing on ergometers; Sullivan and Rickers (2013) had groups of teammates and groups of strangers perform vigorous rowing activity for 45 minutes, and the current study had participants perform the same vigorous rowing activity for 30 minutes on three separate occasions. The duration of time required to produce the synchrony effect remains unexplored. Moreover, including the current results, the synchrony effect has been seen with males and females participating in only the sport of rowing. It may be possible that greater increases in pain threshold were evident following the in-phase synchronous rowing conditions because the sport itself is dependent upon an in-phase motion. Unlike other synchronous exercises where group success can occur in an in-phase or anti-phase manner (i.e., figure skating, gymnastics, cycling, running), rowing demands that the in-phase form of synchrony be linked to the goal of the task. Perhaps greater increases in pain threshold were evident in the in-phase synchronous condition because its engrained in rowers to move in the in-phase form of synchrony, and avert anti-phase synchrony?

Lastly, a weakness can be seen within the protocol of this study. Special methodological concerns are typically brought forward when human participants are used in experiments, mainly because their thoughts about the experiment may in turn, affect their behavior in carrying out the experimental task, a factor referred to as a "demand characteristic" of an experiment (Rosnow, 2009, p.110). Results of an experiment can become biased due to subtle cues given off by an experimenter that create an implicit demand for participants to perform or behave as expected.

It is possible that demand characteristics may have had an effect on results in the present study; participants may have formed an interpretation of the experiment's purpose and subconsciously changed their behaviour to fit accordingly. Rosenthal and Rosnow (2009) articulate that participants' knowledge of the researcher's hypotheses may cause participants to respond by exhibiting behaviors designed to confirm the hypothesis, thereby serving as a "good subject" (p.110). Furthermore, the experimenter was not blinded to the condition of participants; therefore, it is possible that this may have had the capacity to have an effect on the results. For example, in knowing the order of conditions amongst participants, the experimenter may have accidentally treated participants differently in the alone session compared to the in-phase and anti-phase synchronous sessions. Additionally, by not being blinded to conditions, the experimenter may have seen greater increases in pain threshold (i.e. inflated the cuff to a greater extent) in the in-phase synchronous condition and not the anti-phase synchronous condition, when in fact, none really existed. Also, because participants were repeatedly performing the test, they may have become accustomed to pain threshold being measured and could simply withstand more pressure in subsequent training sessions.

Moreover, inferences of endorphin activity were taken through an indirect measure - pain threshold. Pain is acknowledged to be a subjective experience, for which the gold standard of measurement is self-report (Brown, Chatterjee, Younger, & Mackey, 2011). This required the experimenter to be present to take measurements of pain threshold via blood pressure cuff assay and listen to each participant self-report pain threshold. However, because only one experimenter was present, the start and end times of synchronized training sessions had to be staggered 30 seconds apart to allow for the appropriate pain threshold test to be completed.

Further research is still required to fully understand this synchrony effect and fully operationalize these potential mechanisms behind it. Until such exploration occurs, the links between synchrony and endorphins and cohesion will remain speculative.

5.4 Future Directions

At this point in time, the synchrony effect appears to be a robust phenomenon. In multiple studies, it has been repeatedly found that vigorous synchronized activity causes an increase in pain threshold, which appears to be an indication of heightened endorphin activity. This effect now appears to be the result of synchrony, and in particular in-phase synchrony, as opposed to social co-action. However, future research is still required to fully understand the mechanics and implications of the synchrony effect.

The present study was limited to using experienced athletes. Future studies should address both experienced and non-experienced rowers. Additionally, the present study looked at a longer duration of exercise. Instead, more intense training for short periods of time should also be examined.

Future studies should also extend to a different variety of sports (i.e. cycling, running, gymnastics) and exercises (i.e., walking, yoga, drumming, tai-chi) to see their affect on pain threshold in both in-phase and anti-phase synchronous settings. This could open up the possibility that the synchrony effect may occur when it comes to less strenuous coordinated tasks like those noted above. Less vigorous coordinated actions, such as tai chi or drumming have also been implicated in social bonding. It could be that the synchrony effect is due to the coordination of the activity regardless of how physically demanding it is.

Literature written within the past few years' supports using a blood pressure pain threshold test as a measure of endorphin levels. This procedure is the most non-invasive assay for central endorphin activity. Comparable designs have used pain threshold as a valid measure of endorphin levels. Should future research remain using the protocol used by Cohen et al. (2010) and Rickers and Sullivan (2013) to measure pain threshold via blood pressure test, a minimum of two experimenters should be used to administer pain threshold tests. This could avoid staggering start and finish times amongst participants, leading to sessions that are synchronized from start until finish and thus, more precise results.

Lastly, future research situations could benefit from using more precise methodologies with regard to the implications of demand characteristics. Researchers could use different approaches to reduce the assumption that participant responses are influenced by knowledge of the researcher's hypotheses. Such approaches could include blinded conditions to help the experimenter remain as neutral as possible in their actions toward research participants, questionnaires proceeding and following testing sessions to examine participants' suspicions about research questions, and making greater effort to maintain the confidentiality of the study and its hypotheses.

To fully understand this phenomenon, more research is needed on the basic mechanics and implications of the synchrony effect. It must be investigated if synchrony directly affects endorphins and if so, does this synchrony induced endorphin activity affect cohesion. Therefore, further research is required to fully operationalize this potential mechanism and define the synchrony effect phenomenon.

5.5 Conclusions

People tend to spontaneously and unintentionally synchronize movements with one another (Miles et al., 2010). More importantly, synchronization between people can influence their subsequent positive social feelings toward one another. This has been demonstrated in a number of experimental studies, involving participants tapping synchronously with an experimenter (Hove and Risen, 2009; Valdesolo and Desteno, 2011), rocking together (Miles et al., 2012) and walking in time with other people (Wiltermuth and Heath, 2009).

Recent research has suggested that endorphins play a central role in the underpinnings of social bonding (Dunbar & Shultz, 2010). According to pain threshold assays, various 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; Sullivan & Rickers, 2013), trigger endorphin release. Specifically, synchronized vigorous activity (like rowing) elevates pain thresholds to a greater extent than non-synchronized exertion (Sullivan & Rickers, 2013). The consistent finding within past research indicates that endorphin release is heightened when activity is performed in synchrony with others compared to in a solitary condition. However, the context and degree of synchrony associated with the synchrony effect is paramount.

When individuals synchronize their actions, two relevant observations can be made. Firstly, as previous research exhibits, social connectedness and rapport are enhanced when behaviour is coordinated in a synchronous manner (Wiltermuth & Heath, 2009, Miles et al., 2009, Dunbar et al., 2011). Secondly, two modes of interpersonal coordination predominate, in-phase and anti-phase synchrony (Haken et al., 1985, Chartrand & Bargh, 1999). Current research suggests that is is the in-phase form of synchrony that further activates endorphin release and produces a more significant elevation in pain threshold than compared to an anti-phase synchrony condition.

The present study extends our understanding of the synchrony effect. It was designed to investigate if two different phases of synchrony would both produce the synchrony effect of elevated pain threshold which has only been documented with in-phase synchrony (Cohen et al., 2010 and Sullivan & Rickers, 2012). The current findings demonstrate that the manner in which behavior is coordinated is an important determinant of the synchrony effect. Within the current study, it was found that when individuals rowed in an in-phase synchronous condition, significantly higher increases were shown in pain threshold compared to both the solitary and anti-phase synchronous conditions. Furthermore, there were no differences between the anti-phase and solitary condition. Thus, the synchrony effect phenomenon appears to be the result of only in-phase synchronous activity. This finding alone, has several implications within the broader context of synchrony and human sociality.

Behavioural synchrony and movements performed together simultaneously are processes central to ritual, affiliation, identity, human expression and several other social and cognitive outcomes. Thus, the effect of synchronized activity on "social bonding", that is, the psychological experience of increased social closeness, evidenced by prosocial behaviors, 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 are involved in social bonding across primate species; they have also been associated with a number of social behaviors in humans such as laughter (Dunbar et al., 2011), synchronized sports (Sullivan & Rickers, 2011), as well as musical activities like singing and dancing (Wiltermuth & Heath, 2009; Valdesolo and Desteno, 2011). As noted previously, it is possible that endorphins mediate affiliative stimuli, such as synchronous movements and affiliation. Furthermore, these synchronized movements cause an endorphin release above and beyond what is induced by exercise itself (Cohen et al., 2010).

While in-phase and anti-phase are both considered stable modes of coordination, reflecting the highest levels of interpersonal rapport (Miles et al., 2009), it is the in-phase type of synchronization that represents an overall attractor state; consequently, it is a more stable state than anti-phase (Haken et al., 1985). Stable interpersonal synchrony creates a "mooring effect" (Marsh et al., 2009) or a union (Macrae et al., 2008) thereby enhancing the experience of connectedness between interacting individuals (Schmidt & Richardson, 2008).

It is possible that through the synchrony effect, vigorous synchronized activity released endorphins which in turn increase social bonding. This thought is consistent with speculation that collective activities increase cohesion among group members in activities such as marching in step, and singing during religious activities (McNeill, 1995). Through the inducement of endorphins, the synchrony effect may serve as a mechanism for this increased cohesion. Moreover, in-phase synchrony appears to have a more powerful effect on outcomes such as cohesion, cooperation, personal affiliation and other prosocial behaviours (Macrae, Duffy, Miles, & Lawrence, 2008). In context with the current study, it appears that specifically in-phase synchrony, which appears to be preferred by people, causes endorphin release.

Acting in synchrony has repeatedly been found to increase interpersonal attraction (Hove & Risen, 2009; Valdesolo, Ouyang & Desteno, 2010), prosocial behavior (Kirschner & Tomasello, 2010; Wiltermuth & Heath, 2009), cohesiveness (Miles et al., 2010), and now pain threshold (Cohen et al., 2010; Sullivan & Rickers, 2013). The current investigation reveals a very apparent and robust effect of such synchronous actions on pain threshold by incorporating the role of endorphins and how they mediate between shared synchronous movements, affiliation and pain threshold.

It may be that endorphins are the neurochemical "glue" that in conjunction with other cognitive mechanisms, enable both human and non-human species to maintain their complex social bonds over extended periods of time. However, to fully understand this phenomenon, the role of endorphins in relation to the synchrony effect must be further investigated. We must come to know if synchrony directly affects endorphins and if so, if synchrony-induced endorphin activity affects cohesion.

The synchrony effect is an alluring and relatively unexplored area; now is the time to conduct further research on the basic mechanics and outcomes required to produce the synchrony effect.

APPENDIX A:

Physical Activity Readiness Questionnaire - PAR-Q (revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

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

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

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

YES	NO	
☐	☐	**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?**
☐	☐	**2. Do you feel pain in your chest when you do physical activity?**
☐	☐	**3. In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	**4. Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	**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?**
☐	☐	**6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	**7. Do you know of <u>any other reason</u> why you should not do physical activity?**

If you answered

YES to one or more questions

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

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

NO to all questions

If you answered NO honestly to <u>all</u> PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

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

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

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

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

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 or GUARDIAN (for participants under the age of majority) ____________________ WITNESS ____________________

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.

1:12

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REFERENCES

Bernieri, F., Rosenthal, R. (1991). Fundaments of Nonverbal Behavior. *Studies in Emotion & Social Interaction. 11* 401-432

Blood, A., Zatorre, R. (2001). Intensely Pleasurable Responses to Music Correlate with Activity in Brain Regions Implicated in Reward and Emotion. *Proceedings of the National Academy of Sciences of the Unites States of America, 98* 11818-11823

Boecker, H., Sprenger, T., Spilker, M., Henriksen, G., Koppenhoefer, M., Wagner, K.J., Valet, M., Berthele, A., Tolle, T.R. (2008). The Runner's High: Opioidergic Mechanisms in the Human Brian. *Cerebral Cortex, 18* 2523-2531.

Brown, J., Chaterjee, N., Younger, J., Mackey, S. (2011). Towards a Physiology-Based Measure of Pain: Patterns of Human Brain Activity Distinguish Painful from Non-Painful Thermal Stimulation. *PLoS One 6*(9) 1-8.

Chartrand, T., Bargh, J. (1999). The Chameleon Effect: The Perception-Behavior Link and Social Interaction. *Journal of Personality and Social Psychology. 76* 893-910

Chartrand, T., Jefferis, V.E., (2003). Case of Nonconscious Mimicry. *Social Judgements: implicit and explicit processes, 14* 290-302

Cohen. E., Ejsmond-Frey, R., Knight, N., Dubnar, R.I.M. (2009). Rowers' high: behavioural synchrony is correlated with elevated pain thresholds. *Biology Latters, 6* 106-108

Connor, R., Smolker, R., Bejder, L. (2006). Synchrony, social behavior and alliance affiliation in Indian Ocean bottlenose dolphins, *Tursiops aduncus*. *Animal Behaviour. 72* 1371-1378.

Davis, M. (1982). Periodicity in communicative behavior. New York: *Human Science Press.*

Dunbar, R.I.M., Baron, R., Frangoou, A., Pearce, E., van Leeuwen J.C., Stow, J., Partirdige, G., MacDonald, I., Barra, V., van Vugt, M., (2011). Social laughter is correlated with an elevated pain threshold. *The Royal Society, 279 1161-1167.*

Dunbar, R. I.M. & Shultz, S. (2010). Bondedness and sociality. *Behaviour. 7* 775-803.

Field, A. (2009). *Discovering Statistics Using SPSS. Third Edition.* London, England. Sage Publications LTD.

Haidt, J., Seder, P.J., Kesebir, S., (2008). Hive Psychology, Happiness, and Public Policy. *Journal of Legal Studies, 37* 133-156.

Haken, H., Kelso, J.A.S., Bunz, H. (1985). A theoretical model of phase transitions in human hand movements. *Biological Cybernetics, 51* 347-356

Harbach, H., Heli, K., Gramsch, C., Katz, N., Hempelmann, G., Teschemacher, H. (2000). β-endorphin (1-31) in the plasma of male volunteers undergoing physical exercise. *Psychoneuroendocrinology, 25* 551-562.

Hove, M.J., Risen, J.L., (2009). It's all in the timing: Interpersonal synchrony increases affiliation. *Social Cognition, 27* 949-960

Keverne, E.B., Martensz, N.D., Tuite, B., (1989). Beta-endorphin concentrations in cerebrospinal fluid of monkeys are influences by grooming relationships. *Psychoneuroendocrinology, 14* 155-161

Kirschner, S., Tomasello, M. (2009). Joint drumming: Social context facilitates synchronization in preschool children. *Journal of Experimental Child Psychology, 102* 299-314

Kirschner, S., & Tomasello, M. (2010). Joint music making promotes prosocial behavior in 4-year-old children. *Evolution and Human Behavior, 31* 354-364

Knoblich, G., Butterfill, S., Sebanz, N. (2001). Psychological Research on Joint Action: Theory and Data, *The Psychology of Learning and Motivation, 54* 59-93

Lakin, J.L., Jefferis, V.E., Cheung, C.M., Chertrand, T.K., (2003). The chameleon effect as social glue: Evidence for the evolutionary significant of nonconscious mimicry. Journal of Nonverbal Behavior, 27 145-162.

Machin, A.J., Dunbar, R.I.M. (2011). The Brain Opioid Theory of Social Attachment: A Review of the Evidence, *Behaviour (in press)*, *148* 22-23

Macrae, C..N., Duffy, O.K., Miles, L.K., Lawrence, J. (2008). A case of hand waving: Action synchrony and person perception. *Cognition, 109* 152-156

Marsh, K. L., Richardson, M.J., Schmidt, R.C. (2009). Social Connection Through Joint Action and Interpersonal Coordination. *Topics in Cognitive Science 1* 320-339

Marsh, K. L., Richardson, M. J., Baron, R. M., & Schmidt, R. C. (2006). Contrasting approaches to perceiving and acting with others. *Ecological Psychology, 18* 1–38.

McNeil, W. H. (1995). Keeping together in time: dance and drill in human history. Cambridge, MA: Harvard University Press.

Miles, L.K., Griffiths, J.L., Richarson, M.J., Macrae, C. N., (2010). Too late to coordinate: Contextual influences on behavioral synchrony. *European Journal of Social Psychology, 40* 52-60

Miles, L.K., Nind, L.K., Henderson, Z., Macrae, N., (2010). Moving memories: Behavioral synchrony and memory for self and others. *Journal of Experimental Social Psychology, 46* 457-560

Miles, L.K., Nind, L.K., Macrae, N., (2009). The rhythm of rapport: Interpersonal synchrony and social perception. *Journal of Experimental Social Psychology, 45* 585-589

Miles J and Shevlin M (2001) Applying Regression and Correlation: A Guide for Students and Researchers. London.

Nelson, E., Panksepp, J., (1998). Brain Substrates of infant-mother attachment: Contributions of opioids, oxytocin, and norepinephrine. *Neuroscience & Biobehaviorl Reviews, 22* 437-452

Overy, K., & Molnar-Szakacs, I. (2009). Being together in time: musical experience and the mirror neuron system. 489-504

Richardson, M.J., Marsh, K.L., Isenhower, R.W., Goodman, J.R.L., Schmidt, R.C., (2007). Rocking together: Dynamics of intentional and unintentional interpersonal coordination. *Human Movement Science, 26* 867-891

Rosenthal, R., Rosnow, R. (2009). Demand Characteristics and the Concept of Quasi-Controls. *Artifacts in Behavioral Research* 110-113

Schmidt, R.C., Carello, C., Turvey, M.t., (1990). Phase transitions and Critical Fluctuations in the Visual Coordination of Rhythmic Movements Between People. *Journal of Experimental Psychology: Hyman Perception and Performance, 16* 227-247.

Schmidt, R.C., Richardson, M.J., (2008). Dynamics of Interpersonal Coordination. *Understanding Complex Systems 281-308*

Sebanz, N., Bekkering, H., Knoblich, G. (2006). Joint Action: Bodies and Minds Moving Together. *TRENDS in Cognitive Science, 10* 70-76

Semin, G.R., Cacioppo, J.T., (2008). Synchronization, Coordination and Co-Regulation. *Grounding Social Cognition, 5* 119-148

Stein, L., Belluzzi, J.D., (2978(. Brain endorphins and the sense of well-being: a psychobiological hypothesis. *Advances in Biochemical Psychoparmacology, 18* 299-311

Sullivan, P. J., Rickers, K (2012). The effect of synchronized activity in groups of teammates and strangers. *Research Quarterly for Exercise and Sport*

Sullivan, P. J., Rickers, K., Gagnon, M., Gammage, K., Peters, S., (2011). The synchrony effect in treadmill running. *Journal of Sport & Exercise Psychology, 33* S188.

Tarr, B., Launay, J., Dunbar, R. (2014). Music and social bonding: “self-other” merging and neurohormonal mechanisms. *Frontiers in Psychology, 5* 1096

Valdesolo, P., Ouyang, J., DeSteno, D. (2010). The rhythm of joint action: Syncrhony promotes cooperative ability. *Journal of Experimental Social Psychology, 46* 693-695

van Leeuwen, M., Veling, H., Baaren, R., Dijksterhuis, A. (2009). The influence of facial attractiveness on imitation. *Journal of Experimental Social Psychology. 45* 1295-1298

van Ulzen, N. R., Lamoth, C. J. C., Daffertshofer, A., Semin, G. R., & Beek, P. J. (2008). Characteristics of instructed and uninstructed interpersonal coordination while walking side-by-side. *Neuroscience Letters, 432* 88–93.

Wiltermuth, S. S. & Heath, C. (2009). Synchrony and cooperation. *Psychological Science. 20* 1-5