INTERPERSONAL SYNCHRONY IN INFANCY

PROSOCIAL EFFECTS OF INTERPERSONAL SYNCHRONY IN INFANCY

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Abstract

Musical behaviours, such as singing, dancing and musical production, encourage high levels of interpersonal synchrony. In adults, interpersonal synchrony (i.e. moving in time with others) has been shown to encourage affiliative behaviours among those involved. People are more cooperative, helpful, and trusting toward people with whom they have moved synchronously compared to asynchronously. Until the present thesis, it was unknown if these affiliative effects of interpersonal synchrony influenced social behaviour from an early age. In Chapter 2, I provided the first evidence that 14-month-old infants are more helpful toward synchronously-compared to asynchronously-moving partners. In Chapter 3, I showed that interpersonal synchrony only boosts infant helping directed toward their synchronously-moving partner, but not a neutral stranger. However, in Chapter 4, I showed that infants are more likely to help the positive affiliate ("friend") of their synchronously-moving partner over the "friend" of their asynchronously-moving partner. Chapter 5 explores how background music in Chapters 2-4 contributed to the overall experience. Here, I found that even in a non-musical context, infants still helped synchronously-moving partners more than asynchronously-moving partners. However, infants were more distressed and took more time to help than in Chapters 2-4, suggesting that music may provide an emotionally regulating context within which interpersonal synchrony can be experienced. Together, these findings suggest that behaviours encouraging high levels of synchronous movement, such as musical behaviours, have important consequences for early social development.

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List of Tables and Figures

List of all Abbreviations and Symbols

ηp^2: Partial eta squared

ANOVA: Analysis of variance.

ANCOVA: Analysis of co-variance

BPM: Beats per minute

χ^2: Chi-square

CI: Confidence interval

d: Cohen's d

F: F-test statistic

GLM: General linear model

IBQ: Infant Behavior Questionnaire

M: mean

MIDI: Musical Instrument Digital Interface

mo: Month

n: sample size

p: p-value

r: Pearson correlation coefficient

s or sec: seconds

SD: standard deviation

SEM: standard error of the mean

t: t-test statistic

Z: z-score

Declaration of Academic Achievement

This thesis consists of four studies published in scientific journals (Chapter 2, 3, 4 and 5).

The author of the present thesis is the primary author of all four manuscripts and was responsible for experimental design, stimulus creation, data collect, analysis, and manuscript preparation. Kathleen Einarson (McMaster University) is the second author on Chapter 2, and assisted with data collection and manuscript preparation. Stephanie Wan (McMaster University) is the second author on Chapter 3, 4, and 5, and assisted with experimental design, data collection, and manuscript preparation. Christina Spinelli (McMaster University) is the third author on Chapter 5, and assisted with data collection and manuscript preparation. Dr. Laurel Trainor (McMaster University), the thesis supervisor, is the final author on all four manuscripts.

Chapter 3, 4, and 5 extend the findings from Chapter 2, and so the methodology and stimuli overlap to certain extents.

Chapter 2 consists of a reprint of the following published journal article with permission from John Wiley and Sons:

Cirelli, L. K., Einarson, K. M., & Trainor, L. J. (2014). Interpersonal synchrony increases prosocial behavior in infants. *Developmental Science*, *17*(6), 1003-1011.

Chapter 3 consists of a reprint of the following published journal article with permission from the Royal Society:

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Chapter 4 consists of a reprint of the following published journal article with permission from John Wiley and Sons:

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Chapter 5 is forthcoming from UC press:

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CHAPTER 1

Introduction

Music is a salient part of an infant's early life. Cross-culturally, mothers sing lullabies to sooth their infants, and sing playsongs to engage their infants (de l'Etoile, 2006; Trehub & Gudmundsdottir, 2015; Trehub et al., 1997). While our musical experiences change over the lifespan, musical engagement (i.e. singing, dancing, and musical production) remains a universally important and common part of life. The pervasiveness of music has raised questions about how the perceptual and cognitive abilities required for musical engagement might have been adaptive for our human ancestors. Pinker (1997) suggests that music is simply "auditory cheesecake" - that is, a byproduct of culture that causes us pleasure. Darwin (1871) speculated about the adaptive function of musical behaviour, and suggested that sexual selection was at play. Other evolutionary pressures that may have led to the biological adaptations necessary for human musical behaviour have also been proposed (for reviews, see McDermott & Hauser, 2005; Huron, 2001; Trainor, 2015). One compelling hypothesis that is gaining a growing body of support views musical behaviours as socially adaptive (Brown, 2000; Dunbar, 2012; Freeman, 2000). If musical behaviours increase group cohesion and encourage individuals in the group to become more socially focused, this would be adaptive at both the individual and the group level (Dunbar, 2012). An individual who is better liked and trusted by peers is better able to take advantage of the benefits of cooperation and reciprocity. A group that is made up of socially adept individuals will be both directly and indirectly more competitive than other groups. Such social selection would ensure that the genes of individuals in socially cohesive groups are more likely to be passed down than genes from individuals in less socially cohesive groups. If musical behaviour increases cohesion between group members, it could therefore be an adaptive social behaviour (Brown, 2000).

Interpersonal synchrony, or the alignment in time of two or more people's body movements, is a common component of musical engagement. Musicians, dancers and singers must synchronize their actions with their co-performers in order to convey their art. Even the layman has an incredible propensity and urge to align their movements with the underlying pulse heard in a piece of music (for a review, see Repp & Su, 2013). This propensity to move to the beat means that individuals in a group, listening and moving to a common musical stimulus, will by default end up achieving interpersonal synchrony with their group members. Therefore, the social benefits of musical engagement may be driven by the social benefits of interpersonal synchrony. Adults who tap, walk, sing, or row in synchrony later display enhanced affiliative behaviours toward synchronously moving compared to asynchronously moving co-actors (e.g., Cohen, Ejsmond-Frey, Knight, & Dunbar, 2010; Hove & Risen, 2009; Wiltermuth & Heath, 2009).

In the present thesis, I examined the effect of interpersonal synchrony in both musical and non-musical contexts on infant social behaviour. I tested 14-month-old infants across a series of experiments to address three previously untested questions. First, do infants display more affiliative behaviours following interpersonal synchrony compared to interpersonal asynchrony? Second, are these affiliative behaviours directed only toward synchronous co-actors, or do they generalize to neutral strangers or affiliates of the co-actor? Third, how does the presence of music during an interpersonally synchronous experience add to the social effects beyond simply providing a means for achieving the synchronous movement? My results provide evidence that 14-month-olds display more helpfulness toward a synchronously compared to an asynchronously moving co-actor, and that this helpfulness is directed to the co-actor and the co-actor's affiliate, but not to a neutral stranger. Furthermore, while the presence of music during interpersonal movement acts as a mood regulator during the course of the experiment, it is not necessary for the social effects of interpersonal synchrony to emerge.

The Social Effect of Interpersonal Synchrony

The social effects of interpersonal synchrony have attracted the attention of researchers over the last decade. These social effects are operationalized in different ways across studies, but can be described generally as behaviours that enhance social affiliation. These are behaviours that adults and even children display when group inclusion is desirable (Lakin & Chartrand, 2003; Over & Carpenter, 2009). Social cohesion can be enhanced through affiliative behaviours such as increased trust among group members, cooperation, helpfulness, ratings of likeability and feelings of empathy.

In musical contexts. Groups or dyads moving synchronously to music experience prosocial benefits. For example, when pairs of 4-year-olds engage in musical versus non-musical play, they are later more helpful and cooperative with one another (Kirschner & Tomasello, 2010). Children (especially those with poor prosocial skills) who take part in group music lessons later show more empathy and prosociality compared to controls (Schellenberg, Corrigal, Dys, & Malti, 2015; Rabinowitch, Cross, & Burnard, 2013). When a group of adults sing together versus asynchronously, they later rate their group members as more trustworthy (Anshel & Kippler, 1988; Wiltermuth & Heath, 2010) and cooperate more in a public goods game (Wiltermuth & Heath, 2010). High-school students who dance together in synchrony versus out of synchrony show higher pain tolerance (a proxy for endorphin release) and higher ratings of prosociality toward co-dancers, but not toward non-involved individuals (Tarr, Launay, Cohen, & Dunbar, 2015). Choral singing in both small and large choirs leads to increased ratings of group closeness and positive affect compared to a control group (a craft or creative writing group) (Pearce, Launay, & Dunbar, 2015). These studies all suggest that engaging in musical behaviours has social benefits. While some of these studies are multimodal, and do not necessarily isolate interpersonal synchrony from other aspects of musical engagement, interpersonal synchrony is a salient part of musical engagement.

In non-musical contexts. The effect of interpersonal synchrony on prosociality can also be measured in non-musical contexts, suggesting that although music may be a very common and salient context in which interpersonal synchrony can be achieved, a musical context is not necessary for such effects to emerge. For example, when adults row synchronously with others versus alone, they later report higher pain thresholds (Cohen et al., 2010). Synchronous versus asynchronous walking encourages cooperation in a public goods game among co-walkers, and increases expectations for group trustworthiness (Wiltermuth & Heath, 2009). Finger tapping synchronously with an experimenter encourages higher participant ratings of experimenter likeability compared to tapping asynchronously, tapping alone, or tapping synchronously with a metronome (Hove & Risen, 2009). In a study by Valdesolo, Ouyang and DeSteno (2010), participants in pairs either sat in facing rocking chairs and rocked synchronously or sat in back-to-back chairs, rocking at non-synchronized comfortable paces. The synchronous pairs were later more successful than asynchronous pairs on a joint action task where, each holding one side of a wooden labyrinth, participants had to work together to move a steel ball along the maze path (Valdesolo et al., 2010). These studies support the hypothesis that interpersonal synchrony, in either musical or non-musical contexts, can encourage affiliative behaviours.

Possible mechanisms. How interpersonal synchrony influences social behavior is still a matter of debate. Some researchers suggest that when we notice someone else moving in synchrony with us, our attention is directed toward this person. Through mere exposure and increased person-perception, we become more comfortable with this individual and more likely to affiliate. Supporting this hypothesis, participants were found to remember more details about another participant's utterances and facial features after tapping their hand to a metronome synchronously with this person versus asynchronously (Macrae, Duffy, Miles, & Lawrence, 2008). In a related study, Woolhouse, Tidhar and Cross (2016) asked ten participants to dance in a group with one another. Over headphones, half listened to one song while the other half listened to another song with a different tempo. Participants remembered more visual details about co-dancers who had been dancing to the same song as them compared to co-dancers who had been dancing to the other song, again suggesting that moving at the same tempo as another person leads to enhanced memory for details about that person (Woolhouse et al., 2016). These findings fit well with Woolhouse and Lai's (2014) eye-tracking experiment, which shows that adults spend more time overall watching a dancer who is moving in synchrony with background music than a dancer who is moving asynchronously with background music.

Another proposed mechanism is that synchronously-moving others may be perceived to be more similar to the self (Overy & Molnar-Szakacs, 2009; Valdesolo & DeSteno, 2011). Therefore, during synchronous interactions, the perception of the self and the perception of the other overlap, and self-other merging occurs. This proposal states that, if we believe someone is more like us, we feel more empathy for that person. In support of this hypothesis, synchronously- compared to asynchronously-moving others have been rated as more similar to the self by both adults (Valdesolo & DeSteno, 2011) and 8-year-old children (Rabinowitch & Knafo-Noam, 2015). With adults, an increase in feelings of self-similarity directly predicted the amount of compassion displayed toward synchronously moving partners (Valdesolo & DeSteno, 2011).

It has more recently been proposed that increased feelings of self-similarity may interact with neurohormonal changes following experiences of interpersonal synchrony (Tarr, Launay, & Dunbar, 2014). These authors have proposed that endorphin release following interpersonal synchrony might influence behaviour. In support of this hypothesis, higher pain thresholds (a proxy for endorphin release) have been found following synchronous rowing versus rowing alone (Cohen et al., 2010) or rowing in anti-phase (Sullivan, Rickers, & Gammage, 2014), and following synchronous versus asynchronous group dancing (Tarr et al., 2015). Interestingly, endorphin release is also associated with music listening activities (for a review, see Tarr et al., 2014).

It should be noted that the effects of synchrony on social behaviour only appear to emerge if the synchronous partner is considered to be a social agent. In one study, participants were asked to tap in- or out-of-synchrony with sounds attributed to a "virtual partner". Participants rated this partner as more likeable after synchronous versus asynchronous movement, but only if the sounds were attributed to another person and not if they were attributed to a computer (Launay, Dean, & Bailes, 2014). Similarly, Hove and Risen (2009) found that ratings of likeability following synchronous versus asynchronous tapping only emerged if the participant tapped with the experimenter, and did not influence behaviour if the participant was simply tapping in synchrony with a metronome.

In sum, the underlying mechanisms that actually lead to a change in social behaviour and feelings of affiliation following interpersonal synchrony are still unclear. It is possible that an enhancement in person perception, feelings of self-similarity and neurohormonal changes all contribute to the emergence of this effect. As this effect has only captured the attention of researchers in recent years, the question of why interpersonal synchrony influences social behaviour has yet to be fully addressed. The research presented in this dissertation focuses mostly on whether this effect emerges early in development, and how interpersonal synchrony directs infant social behaviour.

The Musical World of the Infant

In this section a general overview of musical development in infancy will be presented. As the infant's perceptual systems specialize and mature, their interpretation of musical stimuli becomes increasingly adult-like and culture-specific. The auditory system develops quickly compared to other sensory systems (e.g. vision), and by the second trimester of pregnancy, the fetus' cochlea and cochlear nerve are mature (for a review on human auditory development, see Moore & Linthicum, 2007). Fetuses and newborns can recognize spoken text repeatedly read to them while still in utero by their mother (DeCasper & Spence, 1986; DeCasper et al., 1994). Newborns have reasonably well-developed hearing by the time they are born, though they are not as sensitive as adults are to quiet sounds (Tharpe & Ashmead, 2001), particularly for low-frequency sounds (see Aslin, Jusczyk & Pisoni, 1998 for a review; Olsho et al., 1988). In terms of discrimination, acuity improves greatly over the first 6 months after birth, and complex sound processing continues to improve into childhood (Tharpe & Ashmead, 2001; Werner, 2002).

With musical stimuli, infants prefer to listen to consonant (pleasant sounding) over dissonant (unpleasant sounding) chords by as early as 2 months of age (Trainor & Heinmiller, 1998; Trainor, Tsang, & Cheung, 2002). By this age, infants can also recognize a familiar melody (Plantinga & Trainor, 2009), and by 6 months of age, can even do so when the familiar melody is transposed to a different pitch level (Plantinga & Trainor, 2005). Also, like adults, infants as young as 3 months old show a high-voice superiority effect (i.e., the highest voice in polyphonic music has the most salient pitch) (Marie & Trainor, 2014).

Infants attend to music, and caregivers across cultures sing to their infants using infant directed singing styles (de l'Etoile, 2006; Trehub & Gudmundsdottir, 2015; Trehub et al., 1997). Music also appears to have an emotion regulating effect for infants. By as early as 7 months of age, infants become distressed less quickly if listening to music compared to either infant- or adult-directed speech (Corbeil, Trehub, & Peretz, 2015). The presence of music has also been shown to reduce inconsolable crying in premature hospitalized newborns (Keith, Russell, & Weaver, 2009). Relatedly, when mothers are asked to sooth their distressed infants with either speech only or singing only, 10-month-old infants in the singing condition are soothed more quickly than those in the speech condition (Trehub, Ghazban, & Corbeil, 2015).

Infant rhythm and metre perception. The timing structure of music can be described as the interplay between rhythm, beat and metre. The rhythm refers to the pattern of sound onsets and offsets in the stimulus. The beat refers to the underlying isochronous pulse that can be extracted from the rhythm. The metric structure of music is the hierarchical grouping of these beats (e.g. beats can be grouped in threes for a waltz, or twos for a march). There are still unanswered questions about how our ability to perceive musical timing structures changes with age and experience, but research indicates that infants are sensitive to timing structures from an early age.

By as early as 2 months, infants can discriminate between different rhythm patterns (Chang & Trehub, 1977; Demany, McKenzie, & Vurpilot, 1977) and can detect changes in the tempo of a melody (Baruch & Drake, 1997). Infants may even be sensitive to metrical cues from birth; newborns have a larger evoked response (measured using electroencephalography, EEG) to an omitted beat from a metrically important compared to less important position in a rhythm pattern (Winkler et al., 2009). By as early as 6 months of age, infants can detect metrical structure violations in rhythm patterns (Hannon & Trehub, 2005a).

The detection of metrical structure violations is also influenced by experience with music in the first year after birth. At 6 months, infants can detect these violations in both culturally familiar and culturally unfamiliar patterns

(Hannon & Trehub, 2005a). However, by 12 months, detection of violations in rhythm patterns with culturally familiar metrical structures persists, while the ability to do the same with culturally unfamiliar structures disappears (Hannon & Trehub, 2005b).

Auditory-motor development. The perception of rhythm, beat, and metre is strongly associated not only to auditory perception, but also to our motor systems (see Patel & Iversen, 2014). In fact, when we listen to music and rhythms, areas of the motor cortex as well as the auditory cortex are active (Chen, Penhune, & Zatorre, 2008; Grahn & Brett, 2007; Fujioka, Trainor, Large, & Ross, 2012). Humans are one of the few species capable of aligning their movements to an underlying auditory beat (Patel, Iversen, Bregman, & Schulz, 2009; Schachner, Brady, Pepperberg, & Hauser, 2009; Schachner, 2010). Even 5-month-old infants demonstrate the urge to move to an auditory beat (Zentner & Eerola, 2010). One study showed that infants displayed significantly more rhythmic limb and body movements when listening to music or drumbeats than when listening to speech (Zentner & Eerola, 2010). However, due to the immaturity of the motor system, such movements in response to an auditory beat do not become properly aligned to the beat until later in childhood (Drake, Jones, & Baruch, 2000; Eerola, Luck, & Toiviainen, 2006; Fitzpatrick, Schmidt, & Lockman, 1996). Interestingly, preschool children are better at drumming along to an auditory beat if they are doing so with an experimenter versus alone (Kirschner

& Tomasello, 2009; Kirschner & Ilari, 2013), and will coordinate bouts of drumming with a same-aged peer (Endedijk et al., 2015).

Moving to the beat also shapes the way we hear timing structures; adults are better able to detect timing violations in a sequence of tones if they are drumming along compared to simply listening (Manning & Schutz, 2013; Butler & Trainor, 2015). Movement can also shape metrical interpretations of ambiguous rhythmic patterns in adults as well as 7-month-old infants (Chemin, Mouraux, & Nozaradan, 2014; Phillips-Silver & Trainor, 2005; Phillips-Silver & Trainor, 2007). When infants were held and bounced by an experimenter to either every second or every third beat of a metrically ambiguous rhythm pattern, they later preferred to listen to a version with emphases matching their bouncing experience (Phillips-Silver & Trainor, 2005). In adults, these effects seem particularly driven by activation of the vestibular system (Phillips-Silver & Trainor, 2008; Trainor, Gao, Lei et al., 2009).

In conclusion, infants experience musical stimuli very often in their natural environment, and show early abilities to interpret both the melodic and temporal information conveyed in music. Infants recognize melodies, feel an urge to move along to the beat in these melodies, and such movements work, in turn, to influence beat perception. Young children also demonstrate an urge to coordinate rhythmic movements with others. This section has provided a brief overview of music perception development. The following section reviews infant social development, as this dissertation focuses on the social implications of musical engagement with infants.

The Social World of the Infant

Infant biases for social stimuli. Infants are highly sensitive to social stimuli. They prefer to look at faces over scrambled faces or non-faces (Mondloch et al., 1999; Johnson, Dziurawiec, Ellis, & Morton, 1991), and prefer to listen to speech over non-speech analogues (Vouloumanos & Werker, 2007). They also quickly develop a preference for the social cues from familiar individuals. For example, newborn babies prefer the voice (DeCasper & Fifer, 1980), face (Bushnell, Sai, & Mullin, 1989) and smell (Cernoch & Porter, 1985) of their mother to other women. During the first year after birth, babies prefer to look at joyful faces compared to neutral or angry faces (LaBarbera, Izard, Vietze, & Parisi, 1976), and prefer faces that make direct contact with them compared to faces with averted gazes (Farroni, Csibra, Simion, & Johnson, 2002). If their caregiver suddenly becomes unresponsive (called the still-face paradigm), infants find this very upsetting (Mesman, van Ijzendoorn, & Bakermans-Kranenburg, 2009; Tronick et al., 1978).

Infants also display behaviours that indicate, or at least result in, strategic partner choice. For example, infants show a preference for individuals with familiar characteristics: for example, they prefer same- versus other-race faces (Kelly et al., 2005), and native-language versus non-native language speakers (Buttelmann, Zmyj, Daum, & Carpenter, 2013; Kinzler, Dupoux, & Spelke, 2007;

Kinzler, Dupoux, & Spelke, 2012). They also prefer people who use infant-directed versus adult-directed speech (Schachner & Hannon, 2011). These preferences could simply be a byproduct of a low-level preference for familiarity, but whatever the underlying mechanism, it results in a tendency to approach “in-group” over “out-group” others.

Infants also begin to demonstrate a preference for pro-social others by as early as 5 months of age. If infants watch a neutral puppet receive help from second puppet and be hindered by a third puppet, infants are more likely to later reach out and grasp the “helper” instead of the “hinderer”, suggesting that they use information from observed social interaction to direct their own social behaviour (Hamlin, Wynn, & Bloom, 2007; Hamlin & Wynn, 2012). Infants also start to display an understanding of equity by as young as 15 months, preferring individuals who divide goods among a group evenly compared to those who divide goods unevenly (Burns & Sommerville, 2014). Also, when given a choice to either help an experimenter who previously tried to provide the child with a toy or an experimenter who purposefully kept the toy for herself, 21-month-old toddlers selectively help the “nice” experimenter even though they do not actually receive a toy from either woman (Dunfield & Kuhlmeier, 2010).

The development of prosocial behaviours. Infants start to display prosocial behaviours (behaviours that benefit others) near the end of the first year after birth. There are different kinds of prosocial behaviours, which can broadly be categorized as helping, sharing and comforting (Dunfield, Kuhlmeier, O'Connell, & Kelley, 2011). These three types of prosocial behavior have their own developmental trajectories and may require different kinds of social understanding to emerge (Dunfield et al., 2011; Dunfield & Kuhlmeier, 2013; Svetlova, Nichols, & Brownell, 2010). In fact, the emergence of helping, sharing and comforting are not found to correlate (Dunfield et al., 2011; Dunfield & Kuhlmeier, 2013). Relatedly, neural patterns of resting brain state activation asymmetries in infants, as measured using EEG, have been found to predict helpfulness and comforting in distinct ways (Paulus et al., 2012). However, for all three categories of prosocial behavior, infants' ability to act prosocially requires three steps: 1) recognizing another person's need/distress, 2) identifying an appropriate intervention, and 3) being motivated to provide that intervention (Kuhlmeier, Dunfield, & O'Neill, 2014).

The current dissertation focuses on helping behavior in infants. In order to recognize another person's need or distress when in need of help, infants first must be able to understand goal-directed behavior and intentionality. Infant understanding of goal-directed behavior develops fairly early (Woodward, Sommerville, & Guadjardo, 2001). For example, when 5-month-old infants habituate to a hand repeatedly reaching for a specific toy, they later dishabituate when the hand reaches for a different toy but not when the hand reaches for the same toy in a new location, suggesting that they have encoded the actor's goal (Woodward, 1998). These expectations were not found when the actor was inanimate (for example, a mechanical claw). Interestingly, early experience with goal-directed behaviour encourages understanding such behaviours in others (Sommerville, Woodward, & Needham, 2005). When 3-month-olds wearing "sticky mittens" are given the opportunity to interact with objects that they would otherwise be dexterously unable to manipulate, they later show expectations about goal-directed behaviours in others with respect to these objects (Sommerville et al., 2005). This suggests that infants' own experiences with the world shape how they understand *others'* experiences with the world. These expectations about goal-directed behaviours in others become more complex and abstract in toddlerhood when intentionality is more easily understood. For example, 14-month-old infants are more likely to imitate an actor's behaviours if they seem intentional versus accidental, which suggests that infants are attending to intended goals over action (Carpenter, Akhtar, & Tomasello, 1998).

Warneken and Tomasello (2006; 2007) developed instrumental helping tasks for infants that they have used to demonstrate that infants as young as 14-months-old not only detect need in others, but also recognize the appropriate intervention and are motivated to help. In these tasks, the experimenter attempts to complete a simple goal. For example, they might attempt to pin up a dishcloth on a clothesline with clothespins, or place a stack of books in a cupboard. The experimenter then displays need, for example by needing an object that is out-of-reach (e.g., a dropped clothespin), or by needing to get around an obstacle (e.g. closed cupboard doors). The infant is given a 30-second trial window in which to respond to this need (e.g. by handing the out-of-reach object back or by opening the cupboard door). Only when the experimenter expresses need (but not when they purposefully throw an object aside or demonstrate that their main goal is not being impeded) do the infants display the intervention behaviors. Eighteen-month-olds display helpfulness across a variety of tasks - when objects are out-of-reach, when obstacles are present, or when an experimenter is using the wrong means or achieving the wrong goal. Young chimpanzees respond similarly but to a lesser extent (Warneken & Tomasello, 2007). Fourteen-month-old infants help on out-of-reach tasks, but not on more complex tasks (Warneken & Tomasello, 2006). Fourteen-month-olds are an especially interesting group in which to investigate helpfulness because baseline helping rates are at around 30% for most out-of-reach tasks (Warneken & Tomasello, 2007) and, therefore, there is room to manipulate motivation to help.

In follow-up experiments, researchers found that helping behaviours were uninfluenced by parental presence or encouragement, and that infants help even when they must disengage from a fun task to do so (Warneken & Tomasello, 2013). Additionally, by 2 years old, children even help when the adult gives no cues of need (e.g., reaching for or vocalizing about the object), such as when the experimenter does not notice that a needed object has fallen from a table (Warneken, 2013). Pupil dilation measures in toddlers watching an experimenter in need show sympathetic arousal in response to the need (Hepach, Vaish, & Tomasello, 2012). In these experiments, toddlers were relieved when the experimenter eventually received help, regardless of whether the child was able to provide help or help was given by another (Hepach et al, 2012). This finding has been interpreted as evidence that infants do not help in order to be credited or rewarded (Hepach et al., 2012; Hepach, Vaish, & Tomasello, 2013). In fact, extrinsically rewarding instrumental helping in 20-month-olds actually reduces helping rates (Warneken & Tomasello, 2008).

In summary, infant prosociality emerges by the second year after birth, building on social biases and understanding of goal-direction and intentionality. Infant prosociality is also directed toward specific social partners over others, suggesting that prosociality is a strategic social tool to encourage affiliation with "good" social partners. In fact, such selectivity in infant helping supports partner choice models of reciprocity (Kuhlmeier et al., 2014). Therefore, as a measure, infant instrumental helping is an excellent tool to use when determining what cues infants use to direct this selective prosociality. The following dissertation focuses on whether interpersonal synchrony, in either musical or non-musical contexts, can act as such a cue for directed infant prosociality.

Summary: Thesis Outline and Contributions

Chapter 2, 3, 4 and 5 examine the effect of interpersonal synchrony on the social behaviour of 14-month-old infants. Previous literature has suggested that interpersonal synchrony encourages prosociality between adult dyads and small groups, and potentially between 4-year-old children, but whether such interpersonal synchrony affects infant social behaviour was not previously tested. Furthermore, the question of how this prosocial effect generalizes to those not directly involved in the movement experience, a question addressed in Chapter 3 and 4, had not previously been investigated even in adult populations.

In Chapter 2, I used a novel methodological paradigm to investigate whether interpersonal synchrony between an experimenter and a 14-month-old infant encouraged subsequent infant helping. In these experiments, infants were held by an assistant and gently bounced so that their movements were either in- or out-of-synchrony with the movements of the experimenter facing them. Chapter 2 also investigated whether the predictability of the interpersonal movements contributed to the social effects. The results of Experiment 1 suggest that the predictability of movements does not affect prosociality, but that infants who were bounced synchronously versus asynchronously with the experimenter (in either a predictable or unpredictable way) were subsequently willing to hand back significantly more out-of-reach objects in the instrumental helping tasks. This increase in helpfulness was driven by a specific increase in spontaneous helping (helping within the first 10 seconds of the trial). This suggests that infants not only help more, but that they help faster following interpersonal synchrony compared to asynchrony. In Chapter 2: Experiment 2, I investigated the effects of antiphase bouncing on infant helpfulness, and found that anti-phase bouncing leads to helping rates comparable to those following synchronous bouncing. This suggests that it is the contingent stability of the timed movements, and not necessarily the mirrored nature of in-phase synchronous movements, that drives this social effect. This was the first set of studies to find social effects of interpersonal synchrony in infants, and the first to investigate how beat predictability plays a role in this effect.

In Chapter 3 of this thesis, I investigated how the boost in infant prosociality following an experience of interpersonal synchrony is directed. Specifically, do infants only increase helpfulness directed to the experimenter with whom they bounced synchronously, or does an experience of interpersonal synchrony even encourage helpfulness directed to a neutral experimenter uninvolved in the movement experience? Results support the former – infant helpfulness is boosted following interpersonal synchrony only when directed toward the synchronous movement partner and not the neutral stranger. This suggests that interpersonal synchrony does not simply put infants in a "social mood", but acts as a cue to direct helpfulness toward their synchronously moving social partner.

Chapter 4 further investigates the transfer of prosociality following an experience of interpersonal synchrony. In this experiment, infants first watch a skit between two experimenters. This skit either demonstrates that these two experimenters are affiliates or that they are neutrally independent actors. The infant is then held by the assistant and bounced either in- or out-of-sync with one experimenter. Later, the infant completes the instrumental helping tasks with the second experimenter (blind to the movement condition). Results show that infants will help the second experimenter more following interpersonal synchrony compared to asynchrony with the first, but only if the two experimenters were shown to be affiliates. Helpfulness toward the independently acting experimenter was not influenced by movement experience. This suggests that interpersonal synchrony encourages helpfulness directed not only toward the movement partner, but also members of that person's social network. This experiment has implications not only on the social influence of interpersonal synchrony, but also on third-party relationship understanding and transitivity of prosociality in 14-month-olds.

Chapter 5 investigates how interpersonal synchrony influences infant behavior in a non-musical context. Music is a context within which interpersonal synchrony is easily encouraged as it provides an external beat to which multiple people can synchronize, but interpersonal synchrony has been shown to influence social behaviour in adults even in non-musical contexts. In the experiment of Chapter 5, infants listened to nature sounds (rushing water, rustling leaves) instead of the previously used musical stimuli (Twist and Shout) while being bounced either in- or out-of-synchrony with the experimenter. As hypothesized, infants were again significantly more likely to display helpfulness during the prosocial test phase if they had bounced in- versus out-of-synchrony with the experimenter. However, interesting differences emerged between this experiment and the experiments presented in Chapters 2 – 4. Specifically, across measures (speed of helping, fussiness rate), evidence emerged to suggest that infants in this experiment were generally less happy than infants in the experiments using music. The conclusion from Chapter 5 suggests that while music may not be necessary for social effects of interpersonal synchrony to emerge, it does reduce infant distress and makes them more willing to engage in interpersonal movement.

This thesis contributes to our understanding of infant social behaviour and, more specifically, of how interpersonal synchrony influences social behaviour. Using a novel paradigm, I provide evidence from the youngest age group tested to date on how prosocial behaviour can be shaped by interpersonal movement experiences. Furthermore, interesting implications about how infants direct social behaviour toward "good" social partners, and how infants understand third-party social interactions, arise from these results. This work also provides evidence that music creates a natural and emotion-regulating context within which interpersonal synchrony can shape infant social behaviour. More generally, this thesis has implications on the importance of musical engagement in early development, and on how infant social behaviour can be enhanced by such experiences.

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CHAPTER 2: Interpersonal synchrony increases prosocial behaviour in infants

Cirelli, L.K., Einarson, K.E., & Trainor, L.J. (2014). Interpersonal synchrony increases prosocial behaviour in infants. *Developmental Science, 17,* 1003–1011. doi: 10.1111/desc.12193.

Preface

Interpersonal synchrony has been shown to have important prosocial consequences. In Chapter 2, I present the first investigation to ask whether this effect influences infant prosociality. In order to test this, I looked at helping behaviours of infants after they had been held and bounced either in-synchrony, out-of-synchrony, or anti-phase to the movements of the experimenter. I also investigated how movement predictability contributes to this social effect. Results show that synchronous and antiphase bouncing encouraged significantly more infant helping than asynchronous bouncing. No effect of movement predictability condition was found on infant helping, suggesting that it is the contingency of interpersonal movements and perhaps not the predictability of these movements that drives this social effect.

Abstract

Adults who move together to a shared musical beat synchronously as opposed to asynchronously are subsequently more likely to display prosocial behaviors toward each other. The development of musical behaviors during infancy has been described previously, but the social implications of such behaviors in infancy have been little studied. In Experiment 1, each of 48 14-month-old infants was held by an assistant and gently bounced to music while facing the experimenter, who bounced either in-synchrony or out-of-synchrony with the way the infant was bounced. The infants were then placed in a situation in which they had the opportunity to help the experimenter by handing objects to her that she had 'accidently' dropped. We found that 14-month-old infants were more likely to engage in altruistic behavior and help the experimenter after having been bounced to music in synchrony with her, compared to infants who were bounced to music asynchronously with her. The results of Experiment 2, using anti-phase bouncing, suggest that this is due to the contingency of the synchronous movements as opposed to movement symmetry. These findings support the hypothesis that interpersonal motor synchrony might be one key component of musical engagement that encourages social bonds among group members, and suggest that this motor synchrony to music may promote the very early development of altruistic behavior.

Introduction

Music is present at social events such as religious ceremonies, military activities, and celebrations where within-group social affiliation, emotional bonding, and sharing common goals are desirable (Dissanayake, 2006). The steady underlying beat that can be extracted from music encourages entrained motor movements (Fujioka, Trainor, Large & Ross, 2012; Large, 2000), and recent studies suggest that adults who engage in a task that encourages high levels of interpersonal motor synchrony later display heightened affiliative behaviors toward one another. For example, synchronized walking, singing, and finger tapping lead to increased cooperative behaviors and higher ratings of likeability among those involved (Anshel & Kippler, 1988; Hove & Risen, 2009; Launay, Dean & Bailes, 2013; Valdesolo, Ouyang & DeSteno, 2010; Wiltermuth & Heath, 2009). This effect of interpersonal synchrony on prosocial behaviors that influence social cohesion may result from perceptual and attentional biases toward synchronous counterparts (Macrae, Duffy, Miles & Lawrence, 2008; Woolhouse & Tidhar, 2010), or from appraisals of self-similarity among synchronous group members (Valdesolo & DeSteno, 2011). One study suggests that music also influences social behavior during childhood. Children who participated in a musical game later played together in a more helpful and cooperative manner than children who participated in a non-musical game (Kirschner & Tomasello, 2010), although the specific role of interpersonal synchrony was not measured in this study. Here we test whether interpersonal synchrony promotes prosocial behavior in infancy.

Some aspects of sophisticated musical processing develop early. Young infants prefer musically consonant over dissonant sounds (Trainor, Tsang & Cheung, 2002), they can remember and detect changes in melodies (Plantinga & Trainor, 2009), rhythms (Chang & Trehub, 1977), and timbres (Trainor, Lee & Bosnyak, 2011), and by 1 year of age, they show evidence of enculturation to the timing structures and pitch classes used in the music of their culture (Gerry, Unrau & Trainor, 2012; Hannon & Trehub, 2005; Trainor & Trehub, 1992). Furthermore, early musical processing is influenced by interactions between auditory and motor systems. Infants bounced to an ambiguous rhythm pattern on either every second or every third beat subsequently preferred to listen to the version of that pattern with accented beats matching the pattern to which they had been bounced (Phillips-Silver & Trainor, 2005). Infants who took part in active participatory parent-and-infant music classes showed enhanced musical processing, heightened brain responses to sound, and increased use of prelinguistic gestures after participation, in comparison to infants who were assigned randomly to classes where music was experienced passively in the background (Gerry et al., 2012; Trainor, Marie, Gerry, Whiskin & Unrau, 2012). Most relevantly, infants in the active participatory music-making group also showed more positive social-emotional development.

By their first birthday, infants are also becoming active social agents, who understand that the behavior of others can be goal-directed (see Sommerville & Woodward, 2010, for a review). They are beginning to engage in coordinated activities that require joint attention with another individual (see Moore & Dunham, 1995; Tomasello, Carpenter, Call, Behne & Moll, 2005, for reviews). For example, 12-month-old infants will point to an object in order to inform another person of its whereabouts (Liszkowski, Carpenter, Stri- ano & Tomasello, 2006; Liszkowski, Carpenter & Tomasello, 2008). Altruistic behavior is also emerging at this age; 14-month-olds are motivated to help an experimenter by returning objects that have been dropped (Warneken & Tomasello, 2006, 2007). Young infants quickly form preferences for social agents that help others (Hamlin, Wynn & Bloom, 2007; Hamlin & Wynn, 2012) and visual cues such as attractiveness, gender, and self-similarity influence their social preferences (Kelly, Liu, Ge, Quinn, Slater, Lee, Liu & Pascalis, 2007; Kinzler, Dupoux & Spelke, 2007; Langlois & Roggman, 1987; Quinn, Yahr, Kuhn, Slater & Pascalis, 2002). Twenty-one-month-olds even direct their instru- mental helping behaviors toward adults who previously attempted to provide a toy, regardless of whether the adult succeeded (Dunfield & Kuhlmeier, 2010). Although these children were somewhat older than the infants in the present investigation, these findings suggest that social interactions can later influence infant instrumental helpfulness.

The goal of the present investigation was to determine whether 14-month-old infants use interpersonal motor synchrony in the context of musical engagement as a cue to direct their own prosocial behaviors. If infants are similar to adults, moving to music in synchrony with an adult should encourage infants to feel similar to and/or attentive toward this adult (Macrae et al., 2008; Valdesolo & DeSteno, 2011). This should increase later prosociality directed toward this adult. On the other hand, bouncing asynchronously with an adult should not increase prosociality. We therefore hypothesized that infants would be more likely to display helping behaviors toward an experimenter following an experience of interpersonal synchrony as opposed to interpersonal asynchrony.

We also investigated whether the predictability of the musical movement was important. Typically, musical engagement involves temporal alignment of movements to evenly spaced, predictable beats. Like interpersonal synchrony, being able to predict another person's movements could make person-perception easier, which could then influence later social behavior. In all previous research on the influence of interpersonal musical engagement on social behavior, synchrony and predictability have either been confounded (Kirschner & Tomasello, 2010), or predictability has been held constant across synchronous and asynchronous conditions (e.g., Hove & Risen, 2009; Valdesolo et al., 2010; Wiltermuth & Heath, 2009). To investigate the influence of movement predictability on prosociality, we compared the helping rates of infants bounced to music with evenly spaced (isochronous) and therefore predictable beats to the helping rates of infants bounced to music with unevenly spaced, unpredictable beats.

To investigate these questions, the assistant held and bounced each infant to music while facing the experimenter (see Figure 1 and Movie S1). The infant watched the experimenter, who bounced either in-synchrony or out-of-synchrony with the way the infant was being bounced. To examine the role of movement predictability, the assistant and experimenter either bounced to an evenly spaced, predictable beat while the infant listened to the original version of the song, or they bounced to an unevenly spaced, unpredictable beat while the infant listened to a version of the song distorted in time such that beat-to-beat onsets varied randomly. After this, we tested the infants' willingness to help the experimenter with whom they had previously bounced. Specifically, we measured whether infants would hand back objects to the experimenter that she had 'accidentally' dropped, following the work of Warneken and Tomasello (2007), which shows that 14-month-olds understand the experimenter's intentions, and will sometimes display such spontaneous instrumental helping behaviors.

------------------ Insert Figure 1 Here ------------------

Experiment 1

Participants

Infants were recruited from the Developmental Studies Database at McMaster University. Forty-eight walking infants from English-speaking homes (24 girls; M age = 14.2 months; SD = 0.2 months) completed the experiment. An additional 14 infants were excluded because of excessive fussiness (n = 10) or equipment failure (n = 4). The McMaster Research Ethics Board (MREB) approved all experimental procedures. Informed consent was obtained from all parents.

Phase 1: Interpersonal Movement Phase

Stimuli. Infants heard a 145 s Musical Instrument Digital Interface (MIDI) version of 'Twist and Shout' (by The Beatles) played over loudspeakers. Infants in the 'evenly spaced (predictable) beats' conditions heard the original version of this track (beats per minute (BPM) = 129; Audio S1). Infants in the 'unevenly spaced (unpredictable) beats' conditions heard the modified version of this track, in which the inter-beat intervals changed after each successive beat (Audio S2; SI has stimulus creation details). In this case, because the time interval between beats varied randomly, it was not possible to predict the time of the next beat. The tracks were MIDI generated, so there was no acoustic distortion associated with the tempo changes.

While the infant listened to one of the two versions of 'Twist and Shout', the assistant and experimenter listened to wood block beats on 'bounce instruction tracks' via headphones. These beats were either synchronous or asynchronous with the version of 'Twist and Shout' to which the infant was bounced. Thus there were four bounce conditions: synchronous bouncing/evenly spaced beats; synchronous bouncing/unevenly spaced beats; asynchronous bouncing/evenly spaced beats; asynchronous bouncing/unevenly spaced beats. The assistant and experimenter were instructed to bounce by bending at the knees, so that the lowest point of their bounce aligned temporally with the woodblock sounds. See SI for details on beat track creation, and for analyses that verified that the assistant and experimenter bounced at the appropriate times.

Procedure. Upon arrival, the assistant interacted with the infant while the experimenter explained the procedure to the parent(s). Parents completed three subtests (‘Smiling’, ‘Approach’, and ‘Activity’) of the Infant Behavior Questionnaire (IBQ) (Rothbart, 1981) in order to account for pre-existing individual differences in infants’ sociability and willingness to approach novel objects. The experimenter then left the room while the assistant exposed the infant to the objects that would later be used in the helping tasks. The assistant identified each item (paper ball, clothespin, marker) by name, and offered the items to the infant. Once the infant touched each of the three objects, the Interpersonal Movement Phase began.

The Interpersonal Movement Phase took place in a sound-attenuating chamber. The parent was asked to place the infant facing outwards in the child carrier worn by the assistant. The parent then sat behind this experimenter for the duration of the Interpersonal Movement Phase, out of the infant’s line of sight. The parent listened to masking music via headphones.

The experimenter stood 4.5 feet in front of the assistant and the infant, directly facing the pair. The bounce procedure was initiated via a button press by the experimenter. This simultaneously triggered the onset of the melodic stimuli heard through speakers by the infant and the ‘bounce instruction tracks’ heard through headphones by the assistant and experimenter (see SI for Apparatus details). The assistant and experimenter bounced for 145 s according to the bounce instructions while the infant listened to the melodic stimuli (see video S1 for an example). The assistant and experimenter wore Nintendo Wii remotes at their waists, so that their vertical acceleration over time could be recorded and compared among the four interpersonal movement conditions to ensure appropriate and consistent bounce quality across conditions (see SI for results).

Phase 2: Prosocial Test Phase

Procedure. The infant was placed on a foam mat on the floor of the sound-attenuating chamber. The assistant left the room, and the experimenter began the helping tasks. The order of the three helping tasks was counterbalanced across conditions and between genders.

The present study included three trials each of three instrumental helping tasks based on those developed by Warneken and Tomasello (2007): the paper ball task (experimenter tries to pick up out-of-reach paper balls with tongs and place them into a bucket), the marker task (experimenter draws a picture with markers and ‘accidently’ bumps the markers off the table), and the clothespin task (experimenter clips dishcloths up on a clothesline and ‘accidently’ drops the clothespins she is using).

For all tasks and trials, the experimenter captured the infant’s attention before dropping the target object. Each of the three trials began when the experimenter reached for the target object. For the first 10 s, the experimenter focused her gaze on the desired object. For the next 10 s, she alternated her gaze between the object and the infant. For the final 10 s, she vocalized repeatedly about the object ('my paper ball!', 'my marker!', or 'my clothespin!'). The trial ended either when the infant gave the dropped object to the experimenter or after 30 s. Parents were asked to remain passive and to refrain from communicating with their infant (see SI for task details; S2 for example videos).

Data coding. To calculate overall rate of helpfulness, these tasks were videotaped and later coded by two raters blind to the conditions. During each of the nine trials, video raters assigned one point if the infant handed the desired object to the experimenter within the 30-s trial window. If the infant attempted unsuccessfully to hand back the object, or handed it back once the 30-s trial window had elapsed, the infant was assigned 0.5 points. The mean helping rate across tasks was calculated, and used as each infant's overall rate of helpfulness. Inter-rater reliability for video coding was high, $r = 0.98$. Raters also recorded elapsed time before helping occurred, to calculate scores for spontaneous helping (0–10 s into trial, while experimenter focuses only on the object) and two measures of delayed helping (11–20 s into trial, while experimenter alternates gaze between object and infant; 21–30 s into trial, while experimenter names desired object).

Results

We analyzed the correlation between helping rates and parent-rated IBQ scores on 'smiling', 'approach', and 'activity'. When these measures correlated with the dependent variable in question, they were included as covariates in an ANCOVA analysis. Otherwise, a standard ANOVA is reported.

Overall helping. An ANOVA on overall helpfulness rate (Figure 2), with independent variables synchrony (bouncing in- synchrony; bouncing out-of-synchrony) and beat predictability (evenly spaced and predictable; unevenly spaced and unpredictable), revealed a trend for infants to be more helpful following interpersonal synchrony (50.6%, SEM = 6.1%) compared to asynchrony (34.0%, SEM = 6.6%), $F_{(1,44)} = 3.45$, $p = .07$, $\eta_p^2 = 0.07$. The main effect of beat predictability, $F_{(1,44)} = 2.56$, $p = .12$, and the interaction between synchrony and beat predictability were not significant, $F_{(1,44)} = 0.11$, $p = .75$.[1]

------------------- Insert Figure 2 Here --------------------

Spontaneous and delayed helping. A similar ANOVA on spontaneous helpfulness (within 0–10 s) revealed that infants were significantly more likely to demonstrate spontaneous helping following interpersonal synchrony (25.8%, SEM = 4.3%) compared to interpersonal asynchrony (13.1%, SEM = 3.9%), $F_{(1,44)} = 4.75$, $p < .05$, $\eta_p^2 = 0.10$. Neither the main effect of beat predictability ($F_{(1,44)} =$

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[1] Due to the non-normality of this sample (Shapiro-Wilk = 0.92, p < .05) we repeated the analysis using trimmed means, a more robust measure of central tendency (Brown & Forsythe, 1974; Field, 2009). Infants with the highest and lowest overall helping score from each of the four groups were removed for this analysis. With this adjusted sample, overall helpfulness correlated significantly with parent-rated IBQ scores of 'approach' (infants likelihood to shy from novelty), $r = -0.38$, $p < .05$. Using an ANCOVA on the trimmed means, controlling for the effects of 'approach', the main effect of synchrony reached significance, $F_{(1,35)} = 5.38$, $p < .05$, $\eta_p^2 = 0.13$. There was still no significant main effect of beat predictability, $F_{(1,35)} = 2.25$, $p = .14$, and no significant interaction between the two variables, $F_{(1,35)} = 0.20$, $p = .66$.

1.31, $p = .26$) nor the interaction between synchrony and beat predictability ($F_{(1,44)} = 0.73$, $p = .40$) was significant.

The two measures of delayed helping (10–20 s; 20–30 s post-trial onset) did not differ statistically and so their values were combined into one measure for delayed helping (>11 s into the trial). Delayed helpfulness rates (>10 s) correlated significantly with the IBQ scale of 'approach', $r = -0.39$, $p < .01$. Infants who were rated as less likely to shy from novelty were more likely to display delayed helpfulness. An ANCOVA controlling for the variability explained by 'approach' scores was conducted on delayed helpfulness. The main effects of interpersonal synchrony ($F_{(1,44)} = 0.35$, $p = .56$), beat predictability ($F_{(1,44)} = 1.54$, $p = .22$), and their interaction ($F_{(1,44)} = 0.17$, $p = .68$) were not significant.

These results suggest that synchrony specifically encourages spontaneous helping, but not delayed helping. Spontaneous helping occurs quickly and before the experimenter directs her attention toward the infant, which may reflect an early form of altruism. Delayed helping occurs after the experimenter involves the infant through her gaze direction and vocalizations, and therefore may reflect compliance rather than altruism. The correlational results further suggest that spontaneous and delayed helping are dissociable, and that only delayed helping is related to personality traits.

Post-hoc video rating results. To verify that the experimenter acted consistently across conditions during both phases of the experiment, two video discrimination tasks were performed (see SI for details). In the first task, 16 naïve adults watched paired videos of the experimenter's face and torso during the Interpersonal Movement Phase. A one-sample t-test revealed that raters' ability to distinguish whether the experimenter was in a synchronous or an asynchronous bouncing condition was not significant, $t_{(15)} = 1.11$, $p = .28$. A paired-samples t-test revealed that raters did not rate the level of happiness displayed by the experimenter differently in the synchronous versus asynchronous conditions, $t_{(15)} = 0.90$, $p = .38$. In addition, the average happiness ratings for each video did not correlate significantly with the helpfulness scores of the infants from that session, $r = 0.10$, $p = .57$.

In the second post-hoc video discrimination task, a separate group of 16 naïve adults watched paired videos showing experimenter behavior during the Prosocial Test Phase (see SI for details). One-sample t-tests revealed that raters did not significantly distinguish the experimenter's interactions with infants from the synchronous/evenly spaced beat condition from her interactions with infants from the asynchronous/ unevenly spaced beat condition. This was true both when the infant did or did not help the experimenter ($t_{(15)} = 0.52$, $p = .61$; $t_{(15)} = 1.07$, $p = .30$). The results of these two video rating tasks indicate that differences in infants' helping behaviors cannot be attributed to noticeable experimenter bias during either phase of the experiment.

Experiment 2

In Experiment 1, we defined synchrony as in-phase interpersonal movement. However, anti-phase interpersonal movement is also a stable form of oscillatory movement, even though such actions alternate rather than mirror each other (Schmidt, Carello & Turvey, 1990; Haken, Kelso & Bunz, 1985). Specifically, if two individuals are bouncing in an anti-phase relationship, when one person is at the lowest part of their bounce the other is at the highest, and vice versa. Both are still moving in the same manner and at the same tempo, but in an opposite phase relationship. If movement contingency drives the prosocial effect of interpersonal motor synchrony, then anti-phase and in-phase synchronous movement should both lead to comparable social effects. If, instead, the social effect of synchronous movement is driven by movement symmetry, then anti-phase movement should not lead to comparable prosocial effects. In Experiment 2, we investigated this hypothesis with 14- month-old infants.

Participants

Twenty walking infants from English-speaking homes participated (10 girls; M age = 14.4 months; SD = 0.5 months). An additional three infants were excluded due to excessive fussiness.

Procedure

The procedure was identical to the procedure for the synchronous/evenly spaced condition of Experiment 1 with the following exception: although the assistant still bounced the infant so that the low part of her bounce aligned with the woodblock sounds on the downbeats, the experimenter instead bounced so that the high part of her bounce (with legs fully extended) aligned with the woodblock sounds on the downbeats. This resulted in alternating bounces; when the assistant and infant were at the top of their bounce the experimenter was at the bottom, and vice versa.

Results

There was a trend for a positive correlation between helpfulness and IBQ-rated 'smiling', $r = 0.41$, $p = .07$, and a significant correlation between helpfulness and 'approach', such that infants less likely to shy from novelty were more likely to help, $r = -0.50$, $p < .05$.

Overall helping. The helping rates of the infants in the anti-phase bouncing condition were compared to the helping rates of infants in the 'synchronous' and the 'asynchronous' conditions from Experiment 1, using two a priori planned comparisons. Two GLM ANCOVAs with 'smiling' and 'approach' as covariates revealed that, while the overall helping rates of infants in the anti-phase condition (M = 47.8%, SEM = 6.6%) were not significantly different from the helping rates of the infants in synchronous condition, $F_{(1, 40)} = 0.14$, $p = .71$, infants in the anti-phase condition were significantly more likely to display helpfulness than infants in the asynchronous condition, $F_{(1, 40)} = 4.50$, $p < .05$, $\eta_p^2 = .10$ (see Figure 2). This indicates that, like synchronous bouncing, anti-phase bouncing leads to a boost in the prosocial behavior of 14-month-olds.

Spontaneous and delayed helping. We repeated the analyses above for spontaneous helpfulness (0–10 s) and found that helping rates in the anti- phase condition did not differ from helping rates in synchronous condition of Experiment 1, $F_{(1, 40)} = 0.01$, $p = .96$, but did differ significantly from helping rates in the asynchronous condition, $F_{(1, 40)} = 4.78$, $p < .05$, $\eta_p^2 = .11$. For delayed helping, as expected, there were no significant differences across conditions (ps > .5). These results suggest that anti-phase and in-phase synchrony lead to similar increases in spontaneous helping.

Discussion

The results of Experiment 1 demonstrate that experiencing interpersonal synchrony with an unfamiliar adult promotes spontaneous prosocial behavior in 14-month- old infants. The size of the synchrony effect on spontaneous helping was moderate ($\eta_p^2= 0.10$), which is impressive given that this behavioral measure could be influenced by many factors aside from our manipulation (Fritz, 2012), and given the relatively short duration of the interpersonal movement (145 s). Interestingly, interpersonal synchrony specifically encouraged spontaneous helpfulness. Delayed helpfulness was not affected by the synchrony manipulation, but was related to individual differences in willingness to approach novelty and dispositional positivity. The lack of an effect of beat predictability on helpfulness is not surprising given the hypothesis relating interpersonal synchrony to prosociality (Macrae et al., 2008; Valdesolo & DeSteno, 2011). However, because in past studies beat predictability has been consistently confounded with interpersonal synchrony or held constant across conditions, it was important and informative to dissociate these two variables. Overall, these results support the hypothesis that interpersonal motor synchrony influences how prosocial behaviors are directed early in development.

In Experiment 2 we found that a synchronous but anti-phase bouncing experience led to increases in prosocial behavior comparable to in-phase bouncing. Similarly, free-style adult dancers who make synchronous but not identical movements subsequently recall more information about each other than those dancing at different tempos (Woolhouse & Tidhar, 2010). Together, these studies support the hypothesis that it is the contingency and oscillatory stability underlying in- and anti-phase interpersonal movement that drives the effect of interpersonal motor synchrony on prosociality, and not specifically movement symmetry.

Interpersonal motor synchrony may allow involved parties to mark each other as similar to one another (Valdesolo & DeSteno, 2011), which in turn leads to an increase in affiliative behaviors. In infancy, other cues for self-similarity such as race and native language have been shown to contribute to social preference (Kelly et al., 2007; Kinzler et al., 2007). Interpersonal motor synchrony may work similarly, but has also been hypothesized to enhance person-perception by directing attention to synchronously moving counterparts (Macrae et al., 2008). One way to test this hypothesis in future studies would be to measure how much eye contact the infants make with synchronously versus asynchronously moving partners. These results are also consistent with the social cohesion model of musical behavior, which proposes that group musical engagement facilitates cooperation among group members. This heightened cooperation enhances that group's ability to survive both directly and indirectly (Brown, 2000; Freeman, 2000; Roederer, 1984).

The social cohesion model does not specify whether social facilitation is driven by a cue that is restricted to musical behavior, or by a cue that is relevant but not restricted to musical behavior. In the present results, increased helpfulness, a form of prosocial behavior that can enhance group cohesion, was observed regardless of whether interpersonal movements were evenly spaced (and therefore typically musical and highly predictable) or unevenly spaced (and therefore not typically musical and not predictable). Our results are consistent with the idea that social facilitation driven by interpersonal synchrony is not restricted to musical contexts. In fact, it is not clear that music is even necessary as long as movements are synchronous. This is an important question for future research. However, the evenly spaced beats in music provide an especially effective context for encouraging synchronous movement among people. Outside of a laboratory setting, it would be difficult for individuals to coordinate movements occurring at random intervals. As such, musical behaviors are a potentially salient source of interpersonally synchronized movement in everyday life.

Interpersonal synchrony is a common experience in an infant's social world. Caregivers often engage in musical behaviors such as singing, clapping, dancing, and bouncing with their young children. Our results suggest that such activities promote socially cohesive behaviors between infants and caregivers.

Moreover, since the helping behaviors manipulated in this experiment represent an early form of altruism (Warneken & Tomasello, 2006), the results presented here suggest that 14-month- old infants are already using social cues to direct their interpersonal helping, and that interpersonal synchrony is one such cue.

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Supporting Information

Interpersonal Movement Phase Stimuli

Infants in the evenly spaced (predictable) beat conditions listened to the original MIDI version of Twist and Shout, whereas infants in the unevenly spaced (unpredictable) beat conditions listened a modified version of this track which was created using GarageBand 6.0.4. The term 'beat' is used here to describe the pulse at the quarter-note level in a common (4/4) time. In this unevenly spaced beats stimulus, each inter-beat interval was one of 13 possible durations ranging from 681 ms (tempo of 88.1 BPM) to 249 ms (241.0 BPM) in 36 ms intervals, chosen to comply with previously established just noticeable difference limens for tempo in adults (Thomas, 2007). These possible durations were applied to each inter-beat interval in a random order. The bounce instruction tracks played to the assistant and experimenter were also created using GarageBand 6.0.4, and contained three parts: 1) pink background noise playing throughout to mask external sounds, 2) single piano tones (E4), lasting 200 ms whose onset preceded the downbeat by 200 ms, and 3) a woodblock sound, marking each downbeat and fading away after about 100 ms from onset. The piano tone was added in as a consistent warning that the downbeat was coming, which served to smooth out the ballistics of the assistant and experimenter's movements during the unevenly spaced beat conditions.

During the two evenly spaced (predictable) beat conditions, while the infant listened to the unmodified version of Twist and Shout, the assistant holding the infant listened to a bounce instruction track that contained evenly spaced piano-tone woodblock pairs occurring every 930 ms; these were phase locked to every second beat in the unmodified isochronous 'Twist and Shout' melody. This instructed the assistant to be at the lowest point of her bounce on every second beat of the melody. If the infant was in the 'synchronous movements-evenly spaced beats' condition, the experimenter also listened to this bounce instruction track. If the infant was in the 'asynchronous movements-evenly spaced beats' condition, the experimenter listened to a bounce instruction track that was played either 33% faster or 33% slower than that of the assistant.

During the two unevenly spaced (unpredictable) beat conditions, while the infant listened to the unevenly spaced version of Twist and Shout, the assistant holding the infant listened to a bounce instruction track that contained unevenly spaced piano-tone woodblock pairs. These sounds were spaced such that the inter-downbeat interval was randomly selected from one of 11 possible intervals. These intervals ranged from 580 ms to 1280 ms, in 70 ms increment steps. These inter-downbeat intervals were chosen to comply with previously established just noticeable difference limens for tempo in adults (Thomas, 2007). These interval ranges differ from those used in creating the unevenly spaced beats version of Twist and Shout because the assistant and experimenter bounced on every second beat while the inter-beat interval of Twist and Shout was manipulated after every single beat. During pilot testing, when given a choice on a five-point Likert scale that ranged from 'highly predictable' to 'highly unpredictable', all of the five adult participants rated the woodblock sound spacing in this track as 'highly unpredictable'. If the infant was in the 'synchronous movements-unevenly spaced beats' condition, the experimenter listened to the same unevenly spaced (unpredictable) bounce instruction track as the assistant. If the infant was in the 'asynchronous movements-unevenly spaced beats' condition, the experimenter listened to a bounce instruction track with inter-beat intervals that were randomized in an order different from the one heard by the assistant.

Apparatus. A Power Macintosh G4 computer with an Audiomedia II sound card played the digital sound files, the presentation of which was triggered via a custom-built button box/interface box and a Strawberry Tree I/O card. The melodic stimuli were played through a Denon amplifier (PMA-480R) to an audiological loudspeaker (GSI) 6.5 feet away from the right side of the infants, in a sound-attenuating chamber (Industrial Acoustics Co.). The 'bounce instruction tracks' were time locked to the melodic stimuli and played for the experimenters through Denon AH-D501 headphones.

Two video cameras (a Canon PowerShot SD1000 and a Samsung 65X Intelli-zoom) recorded the infant and experimenter behavior during both phases of the experiment. During the Interpersonal Movement Phase, we measured the vertical acceleration of the assistant and experimenter using the accelerometers in Nintento Wii remotes. WiiDataCapture_v2.1 (© University of Jyväskylä, Toiviainen & Burger, 2011) recorded this at a resolution of 100 samples per second (see SI for details) on a Macintosh Macbook (OSX).

Prosocial Helping Tasks

Materials. Material included six balls of crumpled paper, a pair of tongs, a clear plastic jar, four markers, a piece of white paper, two dishcloths, six clothespins, and rope to be used as a clothesline.

Paper ball task. The experimenter placed three paper balls and the plastic jar on a two-foot high table, and placed three paper balls on the foam mats in front of the table. She then stood behind the table and used the tongs to pick up each paper ball on the table one by one, placing them in the jar while counting each ball aloud. To initiate a trial, she reached over the table for one of the out-of-reach paper balls on the mat.

Marker task. The experimenter took the four markers and a piece of paper to the same table and knelt behind it. She started drawing a picture, showing the infant the picture throughout the task to gain his or her attention. Then, when the infant was focused on the task at hand, she accidently knocked one of the capped markers off the edge of the table. The trial was initiated when the experimenter reached over the table for the dropped marker.

Clothespin task. The experimenter hung dishcloths on a piece of rope extending across one corner of the sound attenuating chamber, tied approximately four feet off the ground at the lowest point. She demonstrated that the clothespins could be used to hold up the dishcloth by successfully using one to pin up the edge of the dishcloth. She then dropped the next clothespin that she was about to use. The trial began when the experimenter reached over the rope for the fallen clothespin. If the infant handed the clothespin back, the experimenter placed it successfully on the dishcloth. If the infant did not hand it back, a new clothespin was placed successfully on the dishcloth before the next trial began (see video S2 for example trials of this task).

Wii Remote Analyses

Interpersonal synchrony. During the Interpersonal Movement Phase, Nintendo Wii remotes were used to measure the assistant and experimenter's vertical acceleration over time. To measure the level of synchrony between their movements, the vertical acceleration of the assistant was correlated with the vertical acceleration of the experimenter using a 30 second sample of data from the middle portion of the Interpersonal Movement Phase. These data were available for 22 of 48 data sets. Significant strong positive correlations represented high interpersonal synchrony between the two, while non-significant weak correlations represented interpersonal asynchrony. To ensure that the assistant and experimenter were equally synchronous in both interpersonal synchrony conditions, and equally asynchronous in both of the interpersonal asynchrony conditions, the effect of interpersonal synchrony and predictability on acceleration correlations was analyzed using a 2 X 2 factorial ANOVA with the absolute values of correlation between the assistant and experimenter as the dependent variable. As predicted, there was a main effect of interpersonal synchrony ($F_{(1,18)}$=468.45, p<0.001). Their movements in the interpersonal synchrony conditions were significantly more correlated (r=0.77) than those from the interpersonal asynchrony conditions (r=-0.05). As expected, no main effect of predictability ($F_{(1,18)}$=0.48, p=0.50) and no interaction between interpersonal synchrony and predictability were found ($F_{(1,18)}$=1.11, p=0.31).

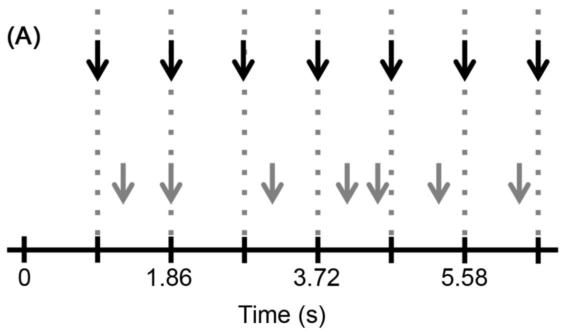
Within-experimenter consistency. To test the assumption that the assistant and experimenter each bounced in a consistent manner across conditions, the variance in each individual's vertical accelerations over time was calculated and compared (Toiviainen & Burger, 2013). Thirty-second samples of data from the middle portion of the Interpersonal Movement Phase were used in this analysis. For the experimenter, these data were available for 27 of 40 data sets. For the assistant, this data was available for 26 of the 40 data sets. A 2 X 2 factorial ANOVA was used to investigate whether there was an effect of interpersonal synchrony and predictability on the variance in the assistant and experimenter's vertical acceleration over time. For the experimenter, there was no main effect of synchrony ($F_{(1,23)}$=0.43, p=0.52) or predictability ($F_{(1,23)}$=2.30, p=0.14) on acceleration variance. There was also no significant interaction between these variables ($F_{(1,23)}$=0.48, p=0.50). For the assistant, there was no main effect of synchrony ($F_{(1,22)}$=0.81, p=0.38) or predictability ($F_{(1,22)}$=1.44, p=0.24) on acceleration variance. There was also no significant interaction between these variables ($F_{(1,22)}$=3.01, p=0.10). These data indicate that the way the assistant and experimenter each bounced during the Interpersonal Movement Phase was consistent across all four conditions. This is especially important considering that moving to evenly spaced tones is qualitatively different from responding to unevenly spaced tones. The lack of an effect on movement variability supports the assumption that adding in the warning tone on the beat tracks to smooth out the ballistics of experimenter movements reduced this difference.

Post-hoc Video Discrimination Tasks

Interpersonal movement phase video coding task. To verify that the experimenter interacting with the infants during the Interpersonal Movement Phase behaved consistently across conditions, a panel of 10 adults, naïve to the hypotheses of the experiment, completed this video discrimination task. Clips from different infant sessions were trimmed to display only the experimenter's upper body and face from 60 sec until 90 sec into the bouncing phase. From the 48 infants in the sample, 32 clips were selected. Participants were not used for whom incorrect camera angling or zooming made this specific view uninformative. To give the task context, the raters were told that in each video, only one experimenter is shown. However, there is another adult facing this person, holding a baby, and bouncing either in synchrony with how the person facing them is bouncing, or out of synchrony. The discrimination task consisted of 16 trials. During each trial, two video clips of the experimenter were compared, one from one of the synchrony conditions and one from one of the asynchrony conditions. After each video played, the rater was asked to rate how happy the experimenter looked (on a scale of 1: not happy, to 8: very happy). Afterwards, the rater was asked to determine if video 1 or video 2 displayed synchronous bouncing. Answers were recorded on sheets of paper. For each rater, the same 16 pairings were displayed. Each rater never saw the same video more than once.

Prosocial test phase video coding task. To verify that the experimenter interacting with the infants during the Prosocial Test Phase behaved consistently across conditions, a panel of 16 adults, naïve to the hypotheses of the experiment, completed the video discrimination task. Clips from different infants were trimmed to display the experimenter's behavior during the first trial of the clothespin task. On each trial video clips from two infants were compared, one infant from the interpersonal synchrony/predictability and one infant from the interpersonal asynchrony/unpredictability condition. Clips from these extreme conditions were chosen to increase sensitivity in this coding experiment – if experimenter bias was a factor, it would be most extreme between these two conditions. In total, 18 of these 24 clips were selected, based on video quality and proper camera angling. In each case, both infants either helped or both infants did not help, so that this was not a confounding factor in raters' judgments. After the second video finished playing, the question "Which baby does the experimenter seem to like more?" was displayed on the screen. Adult raters responded either "baby 1" or "baby 2" via a mouse click before the next trial began. Each rater saw 6 trials. For each rater, a different random pairing of the video clips was used, subject to the constraints described above. Each rater never saw the same video more than once. To watch the movies or listen to the audio clips, visit http://psycserv.mcmaster.ca/ljt/LSM/

Figures



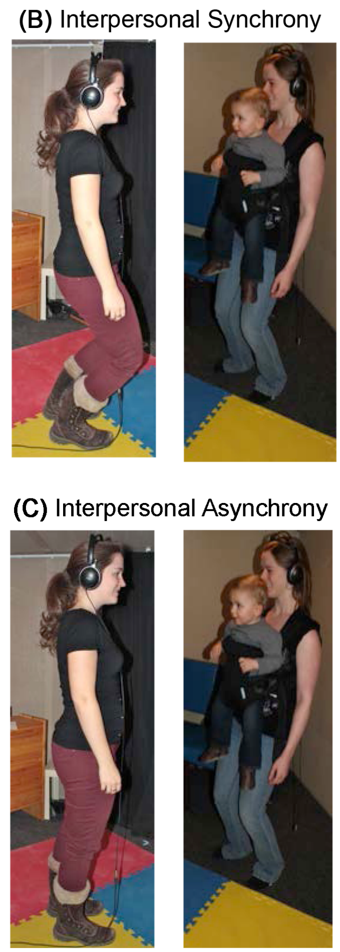


Fig. 1. Between-subject conditions during the Interpersonal Movement Phase. **(A)** A visual representation of how infants were bounced over time. Arrows represent the downbeat, or the lowest point of the assistant and experimenter's bounce. In the evenly-spaced beats conditions (shown in black), downbeats were isochronous and predictable. In the unevenly-spaced beats conditions (shown in gray), the spacing between downbeats varied randomly among 11 preset inter-downbeat-intervals. The assistant and experimenter either bounced **(B)** synchronously or **(C)** asynchronously. In the evenly-spaced beats + asynchrony condition, the experimenter bounced 33% faster or slower than the assistant holding the infant. In the unevenly-spaced beats + asynchrony condition, the assistant and experimenter each bounced to a differentially randomized version of the 11 inter-downbeat time intervals.

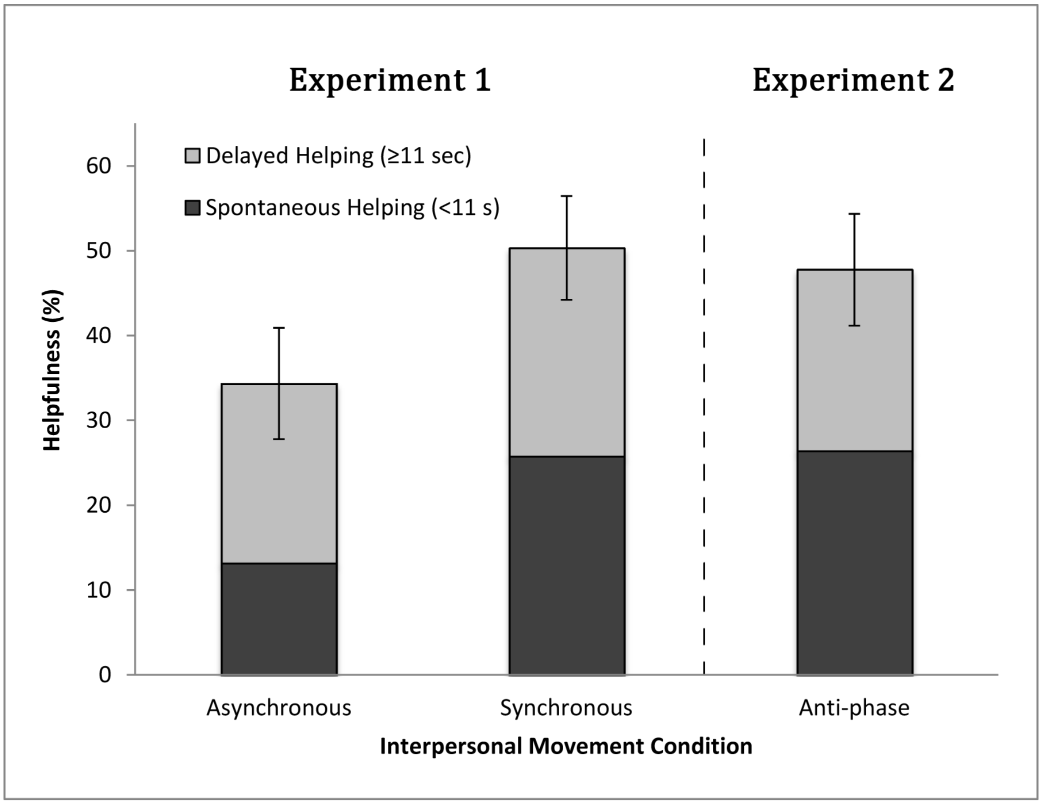


Figure 2: the percentage of objects handed back to the experimenter as a measure of helpfulness (±SEM of overall helping) in Experiment 1 (collapsed across even and uneven beat conditions) and Experiment 2. From this graph, all three measures of helping (overall, spontaneous and delayed) can be visualized. In Experiment 1, infants from the synchronous compared to asynchronous conditions tended to display greater rates of overall helpfulness, and displayed significantly greater rates of spontaneous helpfulness (no effect on delayed helpfulness). In Experiment 2, the rates of overall and spontaneous helpfulness by the infants in the anti-phase condition were comparable to infants from the synchronous condition in Experiment 1: overall and spontaneous helpfulness rates were greater than those of infants from the asynchronous Experiment 1 condition.

CHAPTER 3: Fourteen-month-old infants use interpersonal synchrony as a cue to direct helpfulness

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Preface

In the previous chapter, I found that interpersonally synchronous movement encourages 14-month-old infants to help their movement partner more than interpersonally asynchronous movement. In Chapter 3, I investigate whether this boost in helpfulness is specifically cuing infants to help their synchronous bounce partner, or if it is instead simply priming infants to be generally helpful. To test this, infants were bounced either in or out of synchrony with the main experimenter, and then did helping tasks with both this experimenter and a neutral stranger who had not participated in the interpersonal movement phase. Results replicated our main finding from Chapter 2 – infants who had been bounced in synchrony with their movement partner helped this person more than infants who had been bounced out-of-synchrony. However, movement condition had no effect on stranger directed helping. This suggests that infants are not simply being put into a social mood through synchronous movement. Instead, they are specifically being encouraged to display affiliative behaviours toward their synchronous movement partner.

Abstract

Musical behaviours such as dancing, singing and music production, which require the ability to entrain to a rhythmic beat, encourage high levels of inter-personal coordination. Such coordination has been associated with increased group cohesion and social bonding between group members. Previously, we demonstrated that this association influences even the social behaviour of 14-month-old infants. Infants were significantly more likely to display helpfulness towards an adult experimenter following synchronous bouncing compared with asynchronous bouncing to music. The present experiment was designed to determine whether interpersonal synchrony acts as a cue for 14-month-olds to direct their prosocial behaviours to specific individuals with whom they have experienced synchronous movement, or whether it acts as a social prime, increasing prosocial behaviour in general. Consistent with the previous results, infants were significantly more likely to help an experimenter following synchronous versus asynchronous movement with this person. Furthermore, this manipulation did not affect infant's behaviour towards a neutral stranger, who was not involved in any movement experience. This indicates that synchronous bouncing acts as a social cue for directing prosociality. These results have implications for how musical engagement and rhythmic synchrony affect social behaviour very early in development.

Introduction

Musical engagement is an important social experience throughout our lives (Dissanayake, 2006; Brown, 2000). Even during childhood, engaging in musical activities often occurs in a social context. Infants are rocked to sleep to their mother's lullaby, and preschoolers chant nursery rhymes with schoolmates while jumping rope (Trainor & Hannon, 2012; Trehub & Trainor, 1998). Across cultures, musical engagement such as singing, dancing or playing musical instruments is almost always present at celebrations and religious ceremonies where in-group social affiliation is emphasized (Dissanayake, 2006; Freeman, 2000).

When we engage in musical activities with others, our movements become temporally aligned with our group members as each individual entrains to the underlying beat of the music (Repp, 2006). This type of interpersonal synchrony encourages prosocial behaviour among those involved (Anshel & Kippler, 1988; Hove & Risen, 2009; Kirschner & Tomasello, 2010; Valdesolo, Ouyang & DeSteno, 2010; Wiltermuth & Heath, 2009; Woolhouse & Tidhar, 2010), even in infants (Cirelli, Einarson & Trainor, 2014). However, it is still not clear whether interpersonal synchrony encourages prosocial behaviour indiscriminately or whether it is specific to those with whom temporal synchrony has been previously established. The assumptions of the social cohesion model of musical behaviour suggest that interpersonal synchrony should act as a cue to specifically direct prosociality towards individuals with whom the interpersonal synchrony was experienced (Brown, 2000). Alternatively, it may act as a social prime (Carpenter, Uebel, & Tomasello, 2013; Over & Carpenter, 2009), which would enhance prosociality even towards individuals with whom interpersonal synchrony was not experienced. The present study investigates this distinction in 14-month-old infants, the youngest age group in which an effect of synchronous movement on prosocial behaviour has been measured to date (Cirelli et al., 2014).

Auditory-Motor Interactions and Rhythmic Entrainment

Rhythmic entrainment relies on our ability to extract the underlying beat from a piece of music. Even neonates seem capable of perceiving the beat (Winkler et al., 2009) and people become quite adept at this task by adulthood (Drake, Jones, & Baruch, 2000; Mates, Müller, Radil, & Poppel, 1994; Repp, 2006). Coordinating movements to an auditory beat requires the ability to predict the onset times of future beats in order for the motor system to plan and execute movements at the appropriate times. Infants cannot control their movements well enough to synchronize to a beat, but at 5 months of age, infants engage in more rhythmic movements when listening to music or drumbeats compared to when listening to speech (Zentner & Eerola, 2010). Rhythmic entrainment improves over childhood (Drake et al., 2000) such that adults are able to accurately tap along to a beat when it is in a musically relevant tempo (roughly 300-1800 ms inter-onset-intervals) (Drake & Botte, 1993; Fraisse, 1982; Mates et al., 1994).

While perceiving auditory rhythms primes the motor system for movement Fujioka, Trainor, Large, & Ross, 2012; Grahn & Brett, 2007; Zatorre, Chen, &

Penhune, 2007), the way we *move* also influences how we *perceive* the beat. For example, adults are better at detecting when a drumbeat in a sequence occurs earlier or later than expected if they are tapping along as opposed to simply listening (Butler & Trainor, 2011; Manning & Schutz, 2013). Movement can also affect the perception of ambiguous metrical patterns (without physical accents) in which accented beats could be perceived to be on either every second beat (as in a march) or on every third beat (as in a waltz). In 7-month-old infants as well as adults, moving on every second versus on every third beat of such metrically ambiguous patterns encourages participants to perceive illusory auditory accents that are congruent with their movement (Phillips-Silver & Trainor, 2005; 2007). Perhaps because of this complicated interplay between the auditory and motor systems, humans are one of the few species that can successfully synchronize movements to a musical beat (Patel, Iverson, Bregman & Schulz, 2009; Schachner, Brady, Pepperberg & Hauser, 2009). The ability to align movements with the timing of musical beats makes music a powerful tool for facilitating interpersonal synchrony and accompanying social effects.

Interpersonal Synchrony Encourages Prosocial Behaviour

A growing body of literature suggests that moving in synchrony with others promotes prosocial behaviour. In musical contexts, for example, individuals instructed to sing or drum together are later more likely to help one another (Kokal, Engel, Kirschner, & Keysers, 2011) or cooperate when presented with an economic dilemma (Anshel & Kippler, 1988; Wiltermuth & Heath, 2009).

Additionally, children who engage in play incorporating joint music making have a higher propensity to spontaneously help each other and collaboratively solve a task compared to children who engage in non-musical play (Kirschner & Tomasello, 2010). These findings support the social cohesion model of musical behaviour, which suggests that musical behaviour is evolutionarily adaptive as it enhances prosociality among group members. Such increased group cohesion would be adaptive for individuals if it maintained high in-group reciprocity (Brown, 2000; Gintis, Bowles, Boyd, & Fehr, 2003).

Increased prosocial behaviour following interpersonal synchrony has been noted also in non-musical settings. For example, when participants rated the similarity of two experimenters who waved together, the degree of temporal coordination predicted ratings of inter-experimenter similarity (Lakens, 2010). Comparably, experimenter-participant synchrony during a tapping task predicted participants' compassion responses (Valdesolo & DeSteno, 2011) and reported affiliation ratings toward the experimenter (Hove & Risen, 2009). Also, adults have a greater expectation that their group members will cooperate with them after walking in-step verses out-of-step with one another (Wiltermuth & Heath, 2009). Interpersonal synchrony may also facilitate aspects of social interaction other than cooperation and trust, such as the refining of motor skills required to react appropriately during a joint action task (Valdesolo et al., 2010).

Interpersonal rhythmic synchrony is considered to be a social experience even by young infants. In a previous study we investigated whether the prosocial behaviour of 14-month-old infants could be influenced by interpersonal rhythmic synchrony (Cirelli et al., 2014). Infants were held by an assistant in a child carrier facing forwards and bounced gently to the beat of a song for 2.5 minutes. At the same time, the experimenter faced the infant and also bounced, either in- or out-of-synchrony with the way the infant was bounced by the assistant. Subsequently, we used instrumental helping tasks to measure infants' willingness to aid the experimenter after she accidently dropped the objects needed to complete an intended goal. The number of objects that the infant handed back to the experimenter indexed the degree of prosociality. Infants were significantly more likely to hand back the objects if they had been bounced synchronously compared to if they had been bounced asynchronously with the experimenter (Cirelli et al., 2014). Thus the effect of synchrony on prosocial behaviour can be measured early in development.

Various theories attempt to explain why interpersonal synchrony promotes prosocial behaviour. One idea is that non-musical temporal coordination of movement is linked with the establishment of a social unit. When a person's movements are temporally aligned with those of another, the representation for the perception of self and other might closely overlap, interfering with the ability to differentiate between goals involving the self and the other (Georgieff & Jeannerod, 1998; Hove & Risen, 2009). Expanding this hypothesis is the argument that the main function of synchrony involves increasing perceived similarity, or entitativity (Lakens & Stel, 2011; Valdesolo & DeSteno, 2010). A second idea is that prosocial behaviour resulting from synchronous activities arises from greater mutual attentiveness (Macrae, Duffy, Miles, & Lawrence, 2008; Woolhouse & Tidhar, 2010). For example, dance partners who coordinate their movements to the same song are more likely to remember visual details about each other afterwards (Woolhouse & Tidhar, 2010). In this case, increased cooperation following synchrony may simply be a product of increased communication among the participants (Anshel & Kippler, 1988). A third idea is that the association between synchrony and reward may explain the link between increase cooperativeness and synchrony. Brain activity in the caudate, a region associated with reward, increases when participants are asked to engage in coordinated activities (Kokal et al., 2011). These hypotheses are not mutually exclusive, and a number of factors may drive the prosocial effects of interpersonal synchrony.

However, all of these hypotheses rest on the assumption that interpersonal synchrony generates feelings of prosociality that are directed towards the group members with whom synchrony was experienced. An alternative explanation is that interpersonal synchrony primes prosocial behaviour in general. In other words, individuals may be more likely to behave prosocially following interpersonally synchronous movement, even towards a person with whom they have not experienced synchronous movements. Such social priming using visual or linguistic cues alters the general social behaviour of both adults and young infants (Lakin & Chartrand, 2003; Over & Carpenter, 2009). Additionally, mimicry (which is similar to synchrony) enhances general as well as specifically-directed prosociality in adults (Van Baaren, Holland, Kawakami, & Knippenberg, 2004) and infants (Carpenter et al., 2013), therefore working as a social prime rather than a social cue. If this alternative hypothesis were supported, it would imply that interpersonal synchrony works more as a social prime than a social cue, and does not lead to differentiation between in-group and out-group individuals. One recent study investigating this question using groups of adult participants did not find differences in helpfulness following synchronous movement between group and non-group members (Reddish, Bulbulia, & Fischer, 2013). However, 'prosociality' was measured as the amount of time spent helping an experimenter by completing a questionnaire, which may not be a sensitive measure. Indeed, with this measure, the difference in prosocial behavior following synchronous and asynchronous movement experience was not significant (Reddish et al., 2013).

Purpose

The goal of the present experiment was to investigate whether interpersonal synchrony acts as a cue or a prime for the prosocial behaviour of 14-month-old infants. Instrumental helping behaviours can be reliably measured in a laboratory setting with infants as young as 14 months, because they can typically walk independently to retrieve dropped items, and they understand joint collaborative activities and goal-directed behaviours (Tomasello et al., 2005; Warneken & Tomasello, 2006; 2007). If interpersonal synchrony acts as a cue for

14-month-olds, then we expect infants to selectively direct their prosocial behaviours only towards the person with whom they experienced interpersonal synchrony, and not towards a neutral stranger who is present throughout the experiment but has no involvement in the movement manipulation. According to the assumptions of the social cohesion model of musical behaviour, we hypothesized that the boost in helpfulness by the 14-month-olds following interpersonal synchrony would be specifically directed towards the person with whom they moved synchronously, thereby supporting the social cue hypothesis. Alternatively, if interpersonal synchrony primes infants to be *generally* prosocial, then we expected participants to display prosocial behaviour towards not only the person with whom they experienced interpersonal synchrony, but also an uninvolved neutral stranger.

To investigate this question, 14-month-old infants participated in two phases of the experiment. The interpersonal movement phase involved exposing infants to either synchronous or asynchronous interpersonal bouncing based on random between-subject assignment. This was followed by the prosocial test phase, during which the infants' prosocial behaviours were measured. Three researchers were involved: 1) the assistant, who held and bounced the infant in an infant carrier during the interpersonal movement phase, 2) the experimenter, who faced the infant and bounced either in or out of synchrony with the infant during the interpersonal movement phase, and then later performed half of the prosocial test phase tasks, and 3) the neutral stranger, who sat quietly in the corner reading a book during the interpersonal movement phase, and then later performed half of the prosocial test phase tasks. The roles of experimenter and neutral stranger were counterbalanced between two female researchers. One of these women wore a blue t-shirt while the other wore a yellow t-shirt to help the infant remember their identities.

Method

Participants

Thirty 14-month-old infants (15 girls and 15 boys; *M* age= 14.5 months; SD=0.3 months) were recruited from the Developmental Studies Database at McMaster University. These infants were raised in English-speaking homes, and were able to walk unassisted. Ten additional infants who participated in the experiment were excluded due to excessive fussiness. Consent was obtained from parents, as per the McMaster Research Ethics Board (MREB) guidelines.

Stimuli and Apparatus

Each infant heard a 140 second Musical Instrument Digital Interface (MIDI) version of the Beatle's Twist and Shout. The song was played at 100 beats per minute (BPM) by a Macintosh computer (OSX) through a Denon amplifier (PMA-480R) connected to an audiological loudspeaker (GSI) 6.5 feet away from the right side of the infant (same stimulus as in Cirelli et al., 2014). Both the infant and the assistant holding the infant heard this song stimulus over the loudspeaker. Through Denon AH-D501 headphones, the experimenter (who bounced either in or out of synchrony while facing the infant) listened to the 'bounce instruction track' containing woodblock sounds placed at every second downbeat, overlaid on pink noise. The assistant and infant always heard the song track at 100 BPM. In the synchronous condition, the experimenter also heard the bounce instruction track at 100 BPM, while in the asynchronous condition the experimenter heard the bounce instruction track at 140 BPM. Even though the bouncing of the assistant and experimenter lined up every six seconds, for the most part they were not synchronized. This was confirmed in movement analyses from Wii data (see below).

Procedure

Phase 1: Interpersonal movement phase. When the infant and parent arrived at the lab, the assistant interacted with the infant and exposed him or her to the objects that would later be used during the prosocial test phase. The experimenter obtained parental consent and the parent completed a demographics questionnaire as well as three scales (activity, approach, and smiling) of the Infant Behaviour Questionnaire (IBQ) (Rothbart, 1981). The neutral stranger waited in the sound-attenuating chamber (Industrial Acoustics Co.) where the experiment took place. Thus, neither the experimenter nor the neutral stranger interacted directly with the infant prior to the start of the experiment.

Once the infant was brought into the sound-attenuating chamber, the interpersonal movement phase began. The parent placed their child, facing forwards, in a child carrier worn by the assistant (Infantino Flip ©2012 Infantino LLC. A Step 2 Family Company All Rights Reserved). The parent then sat in a chair behind the assistant and listened to masking music over headphones. The experimenter stood 4.5 feet from the assistant, directly facing her and the infant. Both the experimenter and the assistant bounced in a standing position. The neutral stranger did not interact with anyone during this phase, sitting quietly behind the experimenter within the line of sight of the infant and reading a book (See Figure 1 for a picture of this setup). The assistant bounced up and down at the knees (keeping their feet on the floor), reaching the lowest part of their trajectory at the time of every second downbeat in the song played over loudspeakers. If the infant was randomly assigned to the synchronous bouncing condition, the experimenter bounced in a similar manner to the 100 BPM bounce instruction track, and the infant and experimenter bounced synchronously. If the infant was randomly assigned to the asynchronous condition, the experimenter bounced to the incongruent 140 BPM bounce instruction track, and the infant and experimenter bounced asynchronously at different tempos. In the asynchronous movement condition, the assistant holding the infant was instructed to avert her gaze so that the movement of the experimenter did not influence her ability to bounce to the underlying beats in the song played over loudspeakers (Lucas, Clayton & Leante, 2011). The interpersonal movement phase began when the song files started playing and ended when they stopped, and was therefore 140 seconds in duration.

--------------Insert Figure 1 Here----------------

The assistant and the experimenter both wore Nintendo Wii remotes at their waist while they bounced together, so that their vertical motion over time could be recorded with the internal accelerometers using WiiDataCapture_v2.1 (© University of Jyväskylä, Toiviainen & Burger, 2011). These remotes are often used to measure movement to music, either in individual or group settings [for example, Burger & Toiviainen, 2013; DeBruyn et al., 2008; Phillips-Silver et al., 2011)]. Cirelli and colleagues (2014) also used this equipment to verify that the bouncing was indeed appropriately synchronous and asynchronous depending on the condition. If two people are bouncing in synchrony with one another, their vertical accelerations over time should be highly correlated (they will be accelerating downwards at a similar rate, changing directions at the same time, and accelerating upwards at a similar rate, etc.), whereas if they are bouncing asynchronously, their vertical accelerations over time should not be highly correlated.

Phase 2: Prosocial test phase. During the prosocial test phase, the experimenter and neutral stranger *each* performed two different instrumental helping tasks and one sharing task with the infant (therefore, four helping tasks in total were required). Half of the infants interacted with the experimenter first and then with the neutral stranger, and half interacted first with the neutral stranger. The order of the tasks themselves was held constant: the clothespin task, paper ball task and sharing task followed by the marker task, block task, and sharing task. Each of the instrumental helping tasks was comprised of three trials during which the experimenter or neutral stranger pretended to accidently drop the object that was required to complete the task. During these tasks, the infant could move freely around the soundbooth, and was placed on the floor in the main space by their parent before the tasks began. The infant had a 30 second trial window during which he or she had the opportunity to assist the experimenter by picking up the object and handing it back. During the first 10 seconds of the trial, the experimenter or neutral stranger reached for the object, eye gaze focused on the object. For the next 10 seconds, the experimenter or neutral stranger alternated gaze between the infant and object. For the final 10 seconds, the experimenter or neutral stranger vocalized about the object (i.e. "My marker!" or "My clothespin!"). The trial terminated either when the infant handed the object back or when 30 seconds had elapsed. These tasks were based on the instrumental helping tasks developed by Warneken and Tomasello (2006; 2007).

Clothespin task. In this task, the experimenter or neutral stranger showed the infant a dishcloth, and then clipped one corner of the dishcloth to a clothesline with a plastic clothespin. The first trial was initiated when she attempted to clip up the next corner of the dishcloth, but fumbled and dropped the clothespin to the floor. If the infant handed the clothespin back, the experimenter used it to successfully clip up that corner. If the infant did not hand the clothespin back before the end of the 30 second trial, a new clothespin was used to successfully clip up that corner before the next trial began.

Paper ball task. The experimenter or neutral stranger placed a translucent plastic bucket on a 2.5-foot high table, and held a jar containing six paper balls.

She stood behind the table and successfully tossed one of the paper balls into the bucket, cheered, and showed the infant. The trial began when she attempted to toss the next paper ball into the bucket, and overshot. If the infant handed the paper ball back, she successfully tossed it in the bucket. If the infant did not hand the paper ball back, she took a new paper ball from the jar and successfully tossed it into the bucket before initiating the next trial.

Marker task. The experimenter or neutral stranger placed a sheet of white paper and four coloured markers on the same table. Kneeling behind the table, the experimenter began to draw a flower with the markers, showing the infant her progress along the way. A trial was initiated when she 'accidently' bumped one of the capped markers off the table. If the infant handed the marker back, she used this marker to continue the picture. If the infant did not hand the marker back, she picked up a new marker and used it to continue the picture before initiating the next trial.

Block task. The experimenter or neutral stranger placed two soft baby blocks on the same table beside each other. Standing behind the table, she then grabbed a third block and stacked it on top of this base. The trial was initiated when she attempted to place another block on top of this block, but fumbled the block and dropped it to the ground in front of the table. If the infant handed back the block, she successfully stacked it on the others. If the infant did not hand back the block, a new block was successfully stacked on the others before the next trial was initiated.

Sharing task. The sharing task was based on the request phase of the sharing task used by Schmidt and Sommerville (2011). During each of the sharing tasks (one with the experimenter and one with the neutral stranger), the assistant reentered the sound booth, holding a bucket containing two plastic animal toys. She placed the bucket in front of the infant. If the infant did not immediately pick up one of the toys, she attempted to place one in their hand. Once the infant had at least one of the toys in hand, the experimenter or neutral stranger, sitting on the ground in front of the infant, reached out her hand, palm up, towards the infant asking “Can I have one? Can I have one please?”. She repeated these questions for 30 seconds, or until the infant handed her a toy, at which point she looked at her hand and exclaimed pleasantly “All right!”.

Data coding. Two mounted video cameras (a Canon PowerShot SD1000 and a Samsung 65X Intelli-zoom) were used to capture the infant and experimenter behaviour throughout the two phases. Two adult raters blind to the conditions used this video footage to code infant prosocial behaviour. During each trial of the instrumental helping tasks, infants were given one point if they handed back the object. If they attempted but failed to hand the object back, or handed it back after the 30-second trial window had elapsed, they received 0.5 points. For each instrumental helping task, the per trial points were used to assign a total helping score out of 3 to each infant. Inter-rater reliability was extremely high, r=.997, p<.001. Raters calculated a total score for experimenter-directed helping out of 6 by adding the total helping scores, each out of 3, for each of the 2 instrumental helping tasks performed by this person. Raters calculated a total score for neutral-stranger directed helping in a similar fashion. For each of these conditions (helping towards the experimenter versus the neutral stranger), the percent helping rate was then calculated (score(task 1) + score(task 2)) / 2 tasks X 3 trials X 100%. For the sharing tasks, the raters recorded whether or not the infant shared within the 30-second trial window.

Results

One infant (a female in the synchrony condition) was excluded from the analysis due to missing data (parents did not complete the required IBQ). Using a z-score cutoff of ±2, an additional infant (a male in the asynchrony condition) was removed from the analysis as an outlier.

Helping

Consistent with the hypothesis that increased helpfulness is directed toward the person with whom synchronous movement was experienced, infants who experienced synchronous movement were significantly more likely to help the experimenter (mean=61.3%, SEM=9.4%) than the neutral stranger (mean=38.6%, SEM=8.9%), $t_{(13)}=2.39$, $p<.05$. Helping rates in the asynchronous condition were low and not significantly different toward the experimenter (mean=17.4%, SEM=5.9%) and the neutral stranger (mean=26.8%, SEM=9.4%), $t_{(13)}=-0.93$, $p=.37$.

Significant Pearson correlations were found between infants' rates of helping the neutral stranger and parent ratings (as per the IBQ) for 'smiling'

(r=0.68, p<.01) and ‘approach’ (r=-0.45, p<.05). Specifically, infants who were rated by parents as having a more positive disposition and being less likely to shy away from novelty were more likely to display helpfulness towards the neutral stranger. These correlations were not significant for experimenter-directed helping rates (smiling: r=0.30, p=.12; approach: r=-0.27, p=.16).

An ANCOVA was conducted with condition (synchronous, asynchronous) as a between subjects factor and person (experimenter, neutral stranger) as a within subjects factor, with parent IBQ ratings of ‘smiling’ and ‘approach’ as covariates in the analysis. Results revealed a significant interaction between movement condition and researcher role, $F_{(1,24)}$=8.23, p<.01, η_p^2=0.26 As seen in Figure 2, infants in the synchronous condition were significantly more likely to display helpfulness towards the experimenter than infants from the asynchronous condition [mean=61.3% (SEM=9.4%); mean=17.4% (SEM=5.9%), respectively], $t_{(21.8)}$=-3.94, p<.001, replicating the results of Cirelli and colleagues (2014). However, the difference between synchronous and asynchronous conditions was not significant in the case of the neutral stranger, $t_{(26)}$=-0.92, p=.37. Together, these results show that infants in the synchronous condition were more helpful towards the experimenter than infants in the asynchronous condition, but that this helpfulness did not generalize to the neutral stranger (see Figure 2).

-------------- Insert Figure 2 Here ---------------

Sharing

Two independent samples t-tests were used to investigate the effect of interpersonal synchrony on experimenter- and neutral-stranger-directed sharing. Infants from the synchronous and asynchronous conditions were not significantly different in their sharing rates towards either the experimenter ($t_{(26)}$=-0.82, p=0.42) or the neutral stranger ($t_{(26)}$=-0.82, p=0.42). Overall sharing rates were quite high (25 of the 28 infants in the analysis shared with at least one of the researchers), suggesting that a ceiling effect may have reduced the ability to detect differences between conditions.

Experimenter/Assistant Movement Synchrony Analysis

Wii remote data was available for 19 of the 28 sessions. With these data, correlations between the assistant and the experimenter's vertical acceleration over time during the interpersonal movement phase were calculated as a measure of interpersonal synchrony (for rationale, see section "Phase 1: Interpersonal Movement Phase"). A 30-second long window of data was selected 30 seconds into the interpersonal movement phase. This analysis revealed that the vertical accelerations of the experimenter and assistant were significantly and strongly correlated in the synchrony conditions (mean r=0.75, SEM=0.04) and were weak and non-significantly correlated in the asynchrony conditions (mean r=0.01, SEM=0.003), as expected. An independent-samples t-test was used to verify that the assistant and experimenter's vertical acceleration was significantly more correlated in the synchronous conditions than in the asynchronous conditions,

$t_{(17)}$=-15.50, p<.001.

Experimenter Consistency

Since two researchers took turns playing the role of experimenter and neutral stranger, we wanted to ensure that one researcher was not driving the synchrony effect. An ANOVA with condition (synchronous, asynchronous) and researcher role (Researcher A playing the experimenter, Researcher B playing the experimenter) as two between subjects factors revealed that, as predicted, there was no main effect of researcher role, $F_{(1,24)}$=0.42, p=.84, or interaction between the two variables, $F_{(1,24)}$=0.27, p=.61. This validates the assumption that it was not a single researcher driving the effect of synchrony on experimenter-directed helping.

Post-hoc Video Rating

Adult raters naïve to the hypotheses of the experiment (n=8) watched eight pairs of videos. Each video displayed the experimenter or neutral stranger's behaviours during one trial of the prosocial test phase (the second trial of the second task). Videos were paired so that one researcher's behaviour with an infant from the synchronous condition and an infant from the asynchronous condition were always compared. The videos were also matched so that 1) the two videos always showed the same researcher, 2) the researcher always played the same role (experimenter or neutral stranger), and 3) both infants either helped or did not help. After watching both videos from one of the eight pairs, raters responded to the question: "Which baby does the experimenter seem to prefer?"

Supporting our assumption that the researchers behaved consistently between conditions (synchronous and asynchronous), for both researchers, the raters showed no evidence that the researcher preferred the infants in either the synchronous or asynchronous condition, $t_{(7)}=0.11$, $p=.91$ for Researcher A and $t_{(7)}=-1.80$, $p=.11$ for Researcher B.

Discussion

The results support the hypothesis that interpersonal rhythmic synchrony acts as a social cue, as opposed to a social prime. Infants who were bounced synchronously with the experimenter were more likely to help that experimenter than a neutral stranger with whom they did not experience synchronous movement. Furthermore, infants in the synchronous bouncing condition were significantly more likely to help the experimenter than infants in the asynchronous bouncing condition, but this was not the case for helping directed toward the neutral stranger. Interestingly, socially relevant personality measures from the parent report IBQ (smiling and approach) correlated significantly with helping directed at the neutral stranger but not helping directed at the experimenter, which was driven instead by the experimental manipulation. This suggests that experiencing synchrony with an adult overrides infants' intrinsic tendencies to be more or less helpful in general. The results indicate that interpersonal rhythmic synchrony affects the affiliation between those directly *involved* in the movement experience. This supports assumptions of the social affiliation model of musical engagement by suggesting that in-group affiliation is enhanced by interpersonal synchrony, which is facilitated by mutual musical engagement.

These findings appear to be in conflict with those of Reddish and colleagues (2013), who concluded from their results that interpersonal synchrony may lead to generalized prosociality. However, Reddish and colleagues (2013) tested adults whereas infants were tested in the present study, so it is possible that the effect is person-specific early in development but becomes generalized by adulthood. On the other hand, the conflicting conclusions may be due to other factors such as differences in the sensitivity of the measures of prosocial behaviour across the two studies. The present study used several tasks, all of which had previously been validated with infants (Warneken & Tomasello, 2006; 2007). Reddish and colleagues (2013) used a single measure, the time participants spent filling out forms for the experimenter, which might not have optimally captured participants' prosocial feelings. A further difference between the studies is whether the synchrony was experienced between dyads or within a group. It is possible that prosocial outcomes directed at individuals are strongest when the synchrony is experienced as a dyad. In any case, further studies with adults should be conducted in order to clarify these discrepancies.

In the present study, only instrumental helping and not sharing behaviours were influenced by the experimental manipulations. This might be due to a ceiling effect for the sharing measure. However, there is evidence that helping and sharing represent different types of social engagement and do not necessarily correlate with one another (Dunfield, Kuhlmeier, O'Connell & Kelley, 2011;

Paulus et al., 2013). One clear difference between sharing and instrumental helping is in the goal-directed nature of such behaviours. While sharing typically targets the understanding of even distribution of goods, instrumental helping targets the understanding of goal-directed behaviours (Dunfield et al., 2011). Perhaps the joint activity inherent in interpersonal synchrony specifically encourages prosocial behaviours that rely on the perception of joint action, as would be expected in instrumental helping behaviours. In addition, this sharing measure may have been inappropriate for the age group in question. In the first year after birth, infants tend to share resources indiscriminately. By two years of age, children become more selective about whom they share with, and start sharing at a cost to themselves (Brownell, Svetlova, & Nichols, 2009). It is possible that our ceiling effect represents this indiscriminate sharing behaviour that is typical of this younger age group (Hey, Caplan, Castle & Stimson, 1991). The differential effects of synchrony on sharing and instrumental helping measures in the present study highlight the fact that the way prosociality is measured must be clearly defined in studies of interpersonal synchrony.

It is interesting to note that the movement experience by the infants was passively generated; the infants were not moving to the music on their own; rather, the assistant was passively bouncing them. In older age groups, the effect of synchrony on prosociality has been measured when participants engage in self-generated active movements that aligns temporally with the movement of others (Anshel & Kippler, 1988; Hove & Risen, 2009; Kirschner & Tomasello, 2010;

Valdesolo et al., 2010; Wiltermuth & Heath, 2009; Woolhouse & Tidhar, 2010). In the present experiment and in our previous investigation (Cirelli et al., 2014), the effect was measured in 14-month-olds who experienced passive movement while being held in a carrier and bounced by an adult. Passive movements have been shown to influence beat and meter perception in adults and infants (Phillips-Silver & Trainor, 2005; Phillips-Silver & Trainor, 2008), so it would be interesting to investigate in future research if passive movements can encourage prosociality in adulthood as they do in infancy.

The present results are also of interest when considering the differences between the social implications of mimicry and interpersonal synchrony. While mimicry and synchrony are similar concepts and both can drive prosociality (Hove & Risen, 2009; Van Baaren et al., 2004), they are different phenomena. Unlike in synchrony, in mimicry actions are not synchronous in time, but follow each other (Keller, 2008; Lakins & Chartrand, 2003; Sebanz & Knoblich, 2009). In addition, while synchrony is quite often conscious and intentional, mimicry encourages prosocial effects only if it is undetected by the mimicked individual, and most often happens unconsciously (Ashton-James et al., 2007; Valdesolo & DeSteno, 2011; Valdesolo et al., 2010). Specifically relevant to the above findings, 18-month-old infants who are mimicked by an experimenter are later more likely to display helpfulness towards either that experimenter or a neutral experimenter (Carpenter et al., 2013). In light of these findings, it could be argued that while mimicry acts as an unconscious social prime, interpersonal synchrony is instead an overt and intentional cue for self-other similarity.

One question for future research concerns the generalizability of interpersonal synchrony as a social cue. The present results suggest that interpersonal synchrony does not lead to generalized prosociality with strangers, and is therefore not simply a social prime. However, as a social cue providing information about a specific individual, interpersonal synchrony might still encourage a more restricted kind of generalization. More specifically, the present study investigated the role of synchrony towards an experimenter and a neutral stranger, individuals who did not interact with each other. If the neutral-stranger was not completely neutral, but was instead perceived to be a member of the same group as the bouncing experimenter, prosociality may generalize; infants bounced in synchrony with an experimenter may be more helpful to other members of the experimenter's group, even if they did not bounce with them. The social cohesion model of musical engagement speaks about *group* behaviour, and as such, the social cue provided by interpersonal synchrony might also be a cue containing information about a person's group. This is an interesting question for future research.

Conclusion

The present findings replicate the previous report that interpersonal synchrony increases prosocial behaviour in infants (Cirelli et al., 2014). They additionally support the hypothesis that interpersonal synchrony acts as a cue to direct prosocial behaviour toward individuals rather than as a prime for generalized prosocial behaviour. Future research could profitably focus on the role of music in synchronized movements and the development of methodologies for determining whether experiencing synchronous movement affects social behaviour in infants younger than 14 months of age.

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Figures

Figure 1: Experimental setup for the interpersonal movement phase. The assistant holds the infant facing forwards towards the experimenter, while the neutral stranger sits within the line of the infant's sight, reading silently.

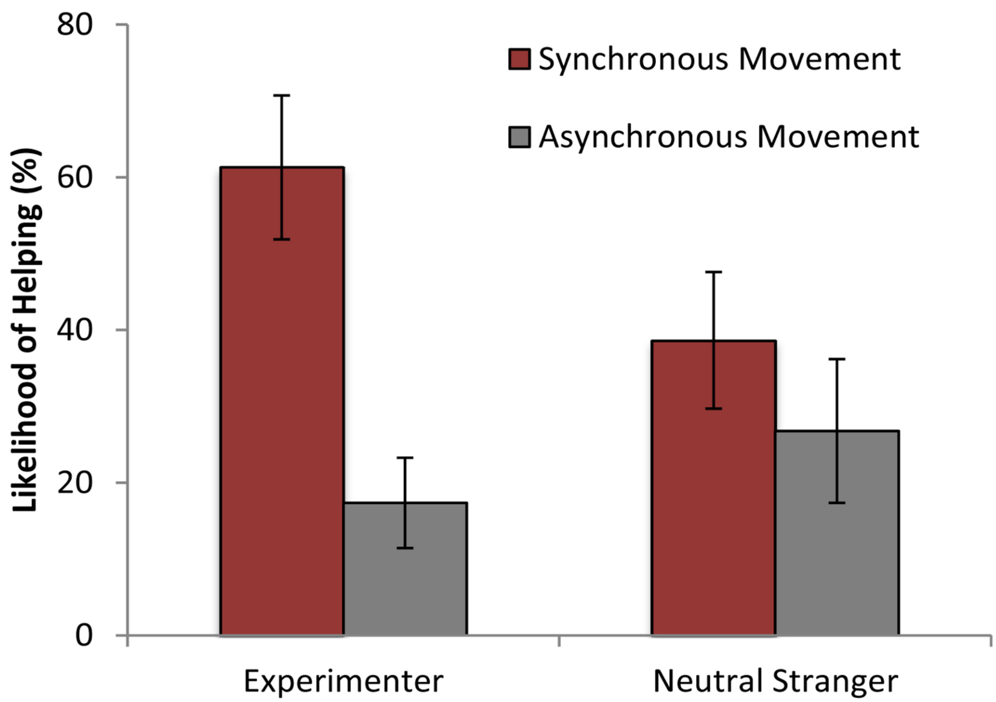

Figure 2. Infant helpfulness towards the experimenter and the neutral stranger by infants in the synchronous compared to the asynchronous condition. Error bars represent standard error of the mean.

CHAPTER 4: Social effects of movement synchrony: Increased infant helpfulness only transfers to affiliates of synchronously-moving partners

Cirelli, L. K., Wan, S. J., & Trainor, L. J. (2016). Social effects of movement synchrony: Increased infant helpfulness only transfers to affiliates of synchronously-moving partners. *Infancy*, doi: 10.1111/infa.12140

Preface

In the previous two chapters, I found that synchronous compared to asynchronous interpersonal movement encourages helpfulness in 14-month-old infants. This boost in helpfulness does not generalize to interactions with a neutral stranger, but seems to specifically enhance affiliation toward the synchronously-moving partner. In Chapter 4, I explore this question of generalizability further. Here, I first had infants watch a live skit between two experimenters. For half the infants, this skit demonstrated that the actresses were positive affiliates. For the other half, this skit demonstrated experimenter independence. Infants were then bounced either in- or out-of-synchrony with one of these actresses, and performed the helping tasks with the other actress. This methodology allowed us to keep the experimenter performing the helping tasks completely blind to the movement condition. If infants performed helping tasks with the positive affiliate of their bouncing partner, they would help this person more following interpersonal synchrony compared to asynchrony. However, as with the neutral stranger in Chapter 3, their helping behaviour toward the independent experimenter was not influenced by their movement experience with the first experimenter. These results suggest that interpersonal synchrony encourages infant prosociality directed to synchronously-moving partners as well as members of that person's social group.

Abstract

Interpersonal synchrony increases cooperation among adults, children, and infants. We tested whether increased infant helpfulness transfers to individuals uninvolved in the movement, but shown to be affiliates of a synchronously-moving partner. Initially, 14-month-old infants (n=48) watched a live skit by Experimenters 1 and 2 that either demonstrated affiliation or individuality. Infants in both groups were then randomly assigned to be bounced to music either synchronously or asynchronously with Experimenter 1. Infant instrumental helpfulness toward Experimenter 2 was then measured. If the two experimenters were affiliates, infants from the synchronous movement condition were significantly more helpful toward Experimenter 2 than infants from the asynchronous movement condition. However, if the two experimenters were not affiliated, synchrony effects on prosociality did not transfer to Experimenter 2. These results show the importance of musical synchrony for social interaction, and suggest that infants may use an understanding of third-party social relationships when directing their own social behaviors.

Introduction

Musical engagement can be a profoundly social experience, enhancing feelings of solidarity amongst participants. Religious rituals often incorporate singing and dancing, and anthems conjure feelings of patriotism (Dissanayake, 2006; Feld, 1984). The social cohesion model of musical behavior suggests that music may be adaptive by increasing within-group cohesion (Brown, 2000). Because of our propensity to align our movements to underlying musical beats (Repp, 2006), moving together in time, known as interpersonal synchrony, is often achieved in a musical context. Recent work on interpersonal synchrony suggests that individuals who move together are more likely to trust and cooperate with one another (Anshel & Kippler, 1988; Kokal, Engel, Kirschner & Keysers, 2011; Launay, Dean, & Bailes, 2013; Reddish, Fischer & Bulbulia, 2013; Wiltermuth & Heath, 2009), rate each other as more likeable (Hove & Risen, 2009), and remember more details about one another (Macrae, Duffy, Miles, & Lawrence, 2008; Valdesolo, Ouyang, & DeSteno, 2010; Woolhouse & Tidhar, 2010). Four-year-old children who sing and move together while playing a game also show increased cooperation and helpfulness toward each other (Kirschner & Tomasello, 2010).

In a previous study, we showed that interpersonal synchrony causes increased helpfulness even in 14-month-old infants, despite their lack of the motor control needed for movement entrainment (Cirelli, Einarson & Trainor, 2014a). Specifically, after being bounced to music in a forward-facing carrier by an assistant for two-and-a-half minutes, infants who watched the experimenter bounce in-sync with them were afterwards more likely to help that experimenter compared to infants who watched an experimenter bounce out-of-sync with them (either too fast or too slow). In a follow-up study, we investigated whether interpersonal synchrony made infants generally more helpful or whether helpfulness was targeted toward the specific person with whom they experienced the synchrony (Cirelli, Wan & Trainor, 2014b). This study replicated the finding of increased infant helpfulness following an interpersonally sychronous bouncing experience, but increased helpfulness did not extend toward a neutral stranger who sat passively in the room during the bouncing experience reading a book. These results suggested that interpersonal synchrony acts as a cue to direct prosocial behavior toward a specific individual rather than as a prime for generalized prosocial behavior.

More recent work with 12-month-old infants has supported the idea that interpersonal synchrony guides social preferences (Tunçgenç, Cohen, & Fawcett, 2015). Infants in this study were more likely to reach for and select a teddy bear who had rocked in-synchrony with them in a car-seat compared to a teddy bear who had rocked out-of-synchrony with them. Such preferences were not found in a non-social control condition, with synchronously and asynchronously moving boxes that were non-agents. This study suggests that at least by 12 months of age, infants already have a desire to affiliate with a synchronously-moving social partner.

These studies support the idea that affiliation is the motivation underlying prosocial behaviors. This idea is also supported by work showing that 18-month-olds primed by a photograph evoking affilation are then more likely to display helping behaviors towards an adult stranger (Over & Carpenter, 2009a). Older children primed to think about ostracism are also more likely to display affiliative imitation toward an adult stranger (Over & Carpenter, 2009b). Together, these studies show that when group inclusion is a goal, we display affiliative behaviors, and that prosocial acts such as helpfulness are a proxy for affiliation.

Prosocial behavior is also related to friendships. Children share more with friends than with strangers (Olson & Spelke, 2008), and expect *others* to share more with their friends than with strangers (Paulus & Moore, 2014). Our studies to date investigating infant helpfulness following interpersonal synchrony (Cirelli et al., 2014a; 2014b) support the idea that infants may socially evaluate synchronously (or asynchronously) moving partners, and use these evaluations to direct their affiliative behaviors. It is possible that synchronous bouncing leads to increased attention, and that infants use the familiarity that might arise from increased attention to assess whether a stranger is a potentially good social partner. We test this in the present study by including a measure of how much the infants looked at the experimenter in the synchronous compared to asynchronous conditions. Whether through attention or some other mechanism, our studies indicate that interpersonal synchrony is one condition that leads to increased affiliation.

Indeed, over the first two years after birth, infants are quickly developing the social and cognitive abilities required to select appropriate social partners. When choosing social partners, infants seem to readily use cues such as attractiveness (Langlois & Roggman, 1987), infant directed speech (Schachner & Hannon, 2011), and acts of prosociality (Dunfield & Kuhlmeier, 2010; Hamlin, Wynn, & Bloom, 2007; Hamlin & Wynn, 2012) to direct their social preferences. They also may use cues to in-group membership, such as race and spoken language, in a similar manner (Kelly et al., 2007; Kinzler, Dupoux, & Spelke, 2007; Pascalis et al., 2005). For example, when interacting with native compared to foreign language speakers, six-month-old infants look longer at native speakers, (Kinzler et al., 2007), ten-month-olds are more likely to accept objects from them (Kinzler, Dupoux, & Spelke, 2012) and 14-month-olds are more likely to mimic them (Buttelmann, Zmyj, Daum, & Carpenter, 2013). Together, these results suggest that infants seem to use social cues to determine who is a part of their social group and who is not, shaping how they behave toward such individuals. Even if these social decisions are simply being driven by mechanisms like familiarity or preference rather than reflecting cognitive evaluations about who is part of an infant's group, the resulting behavior is still an adaptive response that encourages affiliation with in-group members.

By evaluating social interactions that they themselves are not part of, infants also begin to understand third-party coalition over the first two years after birth, and quickly develop the prerequisites for making assumptions about third-party group membership (for a review see Platten, Hernik, Fonagy, & Fearon, 2010). By at least as young as 9 months of age, infants expect that two people who share food quality evaluations will later affiliate, but that two people with opposing evaluations will not (Liberman, Kinzler, & Woodward, 2014). Infants as young as 5 months of age even expect a neutral agent to approach an agent who previously helped them, but avoid an agent who previously hindered them (Hamlin et al., 2007). Hamlin et al.'s experiments (2007, 2012) also show that infants use information about these third-party relationships to direct their own social evaluations, choosing to affiliate with a "helper" over a "hinderer". These studies suggest that infants can use cues such as shared evaluation and valenced interaction to form assumptions about third-party coalitions, and that these assessments influence their own evaluations of these individuals.

The current study extends these findings by exploring whether an infant assesses and integrates social cues about an individual *and* that individual's relationships when directing their social behavior. Namely, if an infant experiences interpersonal synchrony with one experimenter, will they direct prosociality towards a social affiliate of that person? Does interpersonal synchrony act as a cue to direct prosociality not only to an individual, but to that individual's group members as well? Based on principles of transitivity (Hallinan, 1974) and cascading benefits (Levine & Kurzban, 2006), if *A* chooses *B* as a friend, and *B* chooses *C*, then *A* should choose *C*. This concept of transitivity within social networks is related to reciprocal altruism (Trivers, 1971), but adds to the idea that reciprocity in clustered social networks increases payoffs for each member (Levine & Kurzban, 2006). Even preschool children have been shown to achieve triadic closure (becoming friends with their friend's friend) in their preschool classes (Schaefer et al., 2010). Therefore, we predicted that after synchronous (but not asynchronous) bouncing to music with an experimenter, infants would display greater helpfulness toward a second non-bouncing experimenter only if that experimenter demonstrated an affiliation with the first experimenter. If interpersonal synchrony driven by musical engagement is a social cue that encourages not only dyadic prosociality, but also extends to third-party affiliates, this would suggest that musical behavior can act as a social cue in complex social settings.

We also measured the amount of direct eye contact that each infant made with the experimenter during the bouncing experience, to test the person-perception hypothesis of interpersonal synchrony (Macrae et al., 2008). This hypothesis suggests that individuals who move together pay more attention to one another during the movement experience. Work with adults has supported this hypothesis by showing increased attention toward synchronously moving individuals enhances social memory (Macrae et al., 2008; Woolhouse & Tidhar, 2010). We therefore hypothesized that infants in the synchronous movement conditions would make more direct eye contact with the experimenter than infants in the asynchronous movement conditions. Infant temperament was also measured using the parent-report Infant Behavior Questionnaire (IBQ) (Rothbart, 1981), so that personality correlates could be accounted for in our analyses.

Methods

Participants

The 48 14-month-old infants (24 girls; M age = 14.7 months; SD = 0.3 months) who completed the experiment were recruited from the Developmental Studies Database at McMaster University. This sample size was determined before data collection began based on counterbalancing order and power in previous experiments using similar methods. The infants were from homes where English was spoken over 50% of the time. Only infants capable of walking without assistance were recruited, due to the requirement of mobility in the instrumental helping tasks used. The age of 14 months was selected as this is the youngest age at which instrumental helping tasks can be used to reliably measure prosociality (Warneken & Tomasello, 2006; 2007). Participants lived in Hamilton, Ontario or surrounding neighborhoods, and were therefore of mixed ethnicities. An additional 9 infants participated, but were excluded due to excessive fussiness. All experimental procedures were approved by the McMaster University Research Ethics board (MREB) and informed consent was obtained from all parents.

Procedure

The experiment consisted of three phases: 1) the experimenter affiliation familiarization phase, 2) the interpersonal movement phase, and 3) the prosocial test phase. Three researchers were involved: 1) the assistant, who held and gently bounced the infant in time to music in a forward-facing infant carrier during phase 2; 2) Experimenter 1, who performed in phase 1 and then bounced facing the infant during phase 2, but was not involved in phase 3; 3) Experimenter 2 who also performed in phase 1, was not involved in phase 2 (and therefore blind as to whether the infant participated in synchronous or asynchronous movement with Experimenter 1), and later performed instrumental helping tasks in phase 3 (see Table 1). The roles played by the two experimenters were counterbalanced across conditions. The procedures of the interpersonal movement phase and prosocial test phase were based on those used by Cirelli and colleagues (2014a; 2014b). Sex of the participants was also balanced across conditions.

-------------- Insert Table 1 Here ---------------

Familiarization phase. Before the first phase began, the assistant interacted with the infant while Experimenter 1 obtained parental consent. The assistant then exposed the infant to the objects that were later used during the prosocial test phase (i.e. paper ball, clothespin and marker). The parent completed a demographics questionnaire as well as three scales (activity, approach, and smiling) from the IBQ (Rothbart, 1981). At this time, Experimenter 2 waited alone in the sound-attenuating chamber.

Everyone then joined Experimenter 2 in the sound-attenuating chamber. The parent sat on a chair in the corner with the infant on his or her lap. The assistant sat beside the parent. Experimenter 1 and 2 performed one of two dramatic skits, depending on the experimenter relationship condition to which the infant was randomly assigned. For infants assigned to the “experimenter affiliation” condition, the skit demonstrated that the two experimenters were part of the same social group (see SI). They engaged in a friendly dialogue, displayed similar gestures, and independently solved a similar problem (i.e. finding lost hats). For infants assigned to the “experimenter individuality” condition, the skit demonstrated that the two experimenters were independent from one other (see SI). Instead of participating in a friendly dialogue, Experimenter 1 performed a short monologue, and then Experimenter 2 performed a short monologue, but they did not interact together. The monologues were written to match the emotional content, approximate length, and general plot development of the “positive experimenter affiliation” skit.

Interpersonal movement phase. In this next phase, the parent helped place the infant in the forward-facing carrier worn by the assistant, and then sat on a chair behind the pair, out of the infant’s line of sight. Experimenter 2 left the sound booth, thereby remaining blind to the movement condition, and Experimenter 1 stood facing the infant, roughly 4.5 feet away. Experimenter 1 held a button box, and pressed a button to trigger the interpersonal movement phase via Presentation software running on a Windows XP computer. This program presented the 140-second Musical Instrument Digital Interface (MIDI) version of the Beatles’ *Twist and Shout* at 100 beats per minute (BPM) through a Denon amplifier (PMA-480R) connected to an audiological loudspeaker (GSI) 6.5 feet away from the right side of the infant (same stimulus as in Cirelli et al., 2014b). The assistant gently bounced the infant to the beat of this song, bending at the knees so that the lowest part of her trajectory aligned with every second downbeat. Experimenter 1 wore Denon AH-D501 headphones and listened to a bounce instruction track that contained woodblock sounds overlaid on pink noise, and bounced so that the lowest part of her trajectory aligned with these woodblock sounds. In the synchronous condition, this bounce instruction track played at 100 BPM, to ensure that her movements were tempo and phase aligned to the movements of the assistant (and therefore the infant). In the asynchronous condition, this bounce instruction track played at 140 BPM, so that she bounced faster than the assistant and infant and was therefore temporally incongruent with the movement of the infant. It should be noted that the asynchronous condition therefore contained both tempo and phase misalignments between the movement of the infant and the experimenter, as is typically done in adult studies on the effects of synchronous movement (for example, see Hove & Risen, 2009; Valdesolo & DeSteno, 2011; Wiltermuth & Heath, 2009). This point is addressed further in the Discussion. In our previous experiment (Cirelli et al., 2014a), in the asynchronous conditions we used bouncing on the part of the experimenter that was either faster or slower than that of the infant, but found no difference between these two manipulations. Therefore, in the present study we used only faster bouncing on the part of the experimenter in the asynchronous condition.

During this phase, Experimenter 1 recorded in real time when the infant made direct eye contact with her. Because this was coded live, no reliability measures can be reported here. She did this by pressing a button on a small hand-held box that recorded looking-times through Presentation software running on a Windows XP computer so that looking times could be compared between synchronous and asynchronous conditions. The assistant and Experimenter 1 wore Nintendo Wii remotes at their waists to record their vertical motion over time using WiiDataCapture_v2.1 (© University of Jyväskylä, Burger & Toiviainen, 2013). Due to equipment malfunction, these data were not recorded for 16 of the 48 participants. Data were successfully recorded for 14 infants in the synchrony condition, and 18 infants in the asynchrony condition. Following the methods of Cirelli and collegues (2014a; 2014b), these data were used to verify that the vertical accelerations of the assistant and Experimenter 1 were significantly more correlated in the interpersonal synchrony conditions (mean Pearson's r=.62, SEM=0.06) compared to the interpersonal asynchrony conditions (mean Pearson's r=.03, SEM=0.01).

Prosocial test phase. Before beginning the prosocial test phase, the infant was taken out of the carrier, and the assistant and Experimenter 1 left the sound-attenuating chamber. Experimenter 2, who was blind to the movement condition, returned to the booth to perform the instrumental helping tasks. The order of the three tasks (the paper ball, marker and clothespin tasks) was counterbalanced across participants. These measures of infant instrumental helping were developed by Warneken and Tomasello (2006; 2007), and were used in the previous experiments on infant social behavior following interpersonal synchrony (Cirelli et al., 2014a; 2014b). There were three trials per task during which the experimenter dropped an object that she needed in order to complete her goal.

These 30-second long trials were broken down into three parts. During the first 10 seconds of the trial, the experimenter reached for the dropped object, focusing her gaze on the item. For the next 10 seconds, the experimenter still reached for the object but now alternated her gaze between infant and object. During the final 10 seconds, the experimenter explicitly mentioned the name of the desired item (e.g., "my marker!"). The trials ended when the infant handed back the desired object or once 30 seconds had elapsed.

Clothespin task. Experimenter 2 attracted the attention of the infant, showed the infant a dishcloth, and then clipped the dishcloth to a clothesline using one clothespin. When she attempted to clip up the second corner, she pretended to accidently drop the clothespin. She reached for the clothespin for 30 seconds, using the procedure outlined above. At the end of the trial, the experimenter successfully pinned the retrieved clothespin or a new clothespin onto the dishcloth before proceeding to the next trial/task.

Paper ball task. Experimenter 2 attracted the attention of the infant and then successfully tossed a paper ball into a bucket on a 3-foot table in front of her. On her next toss, she initiated the first trial by overshooting, so that the second ball landed in front of the table, out of her reach. After the trial, the experimenter successfully tossed in the retrieved paper ball or a new paper ball before proceeding to the next trial/task.

Marker task. Experimenter 2 attracted the attention of the infant, and then began to draw a picture of a flower using one marker, on the table in front of her. She showed the infant her picture as she continued. While drawing, she initiated the first trial by knocking down another marker that was resting on the table. After the trial, the experimenter either used the retrieved marker or a new one to continue drawing her picture before proceeding to the next trial/task.

Video coding. Video footage, recorded on a mounted Canon PowerShot SD1000, and a Samsung 65X Intelli-zoom or a GoPro HERO3+, was used to later calculate overall helping rates for each infant. There were two raters: the primary rater (author LC), blind to the infant's interpersonal movement condition when coding, and a secondary rater, blind to all hypotheses and conditions. Each rater coded all videos by recording how many of the objects each infant handed back (out of a maximum of 3 objects per task), and when in the trial these objects were handed back. If the infant handed back the object within the 30-second window, they were awarded a full point. If they handed back the object *after* the 30-second window elapsed, they were awarded half a point. Each infant's overall helping rate was calculated as (score[task 1] + score[task 2] + score[task 3]) / (3 tasks X 3 trials) X 100%. In addition to overall helping rates, spontaneous helping rates were calculated as total helping during the first 10 seconds of each trial, and delayed helping as helping 11 seconds or later into each trial. Inter-rater reliability was extremely high, $r=.994$, $p<.001$. The ratings by the primary rater were used in the analyses.

Results

One male infant in the asynchronous/positive-affiliation condition was excluded from the analysis based on a predetermined z-score outlier cutoff of Z=±2 for helpfulness rating[2]. No significant correlations were found between infant overall helpfulness or early or late helpfulness and parent rated IBQ scores on smiling, activity, or approachability (all *p'*s > 0.250).

Overall Helping

The Pearson correlations between helpfulness on each pair of helping tasks were high (Clothespin to Paper Ball, r=.77, p<.001; Clothespin to Marker, r=.75, p<.001; Paper Ball to Marker, r=.70, p<.001). A mixed design ANOVA was used to assess the effect of task order on helpfulness, and to ensure that task order did not interact with movement condition or experimenter relationship condition. There was an effect of task order, in that children were significantly more helpful on the second and third tasks than on the first, $F_{(2,64.9)}=4.16$, $p=.030$. However, there was no significant interaction between task order and either movement condition, $F_{(2,64.9)}=0.24$, p=.725, or experimenter relationship, $F_{(2,64.9)}=0.06$, p=.901, so tasks were collapsed to assess overall helpfulness.

An ANOVA with interpersonal movement condition (synchronous versus asynchronous) and experimenter relationship (affiliate versus individual) as

[2] Removing this participant from the dataset reduces variability in the sample, but it does not change the statistical trends. If this infant is kept in the sample, the interaction between movement condition and experimenter affiliation trends towards significance for Overall Helping ($F_{(1,44)}=3.71$, $p=.06$) and reaches significance for Spontaneous Helping ($F_{(1,44)}=4.98$, $p=.031$). Posthoc tests of these interactions also show the same significant effects as when this participant is removed.

between-subjects factors was used to investigate the effect of these variables on overall infant helpfulness. Consistent with our hypothesis, there was a significant interaction between interpersonal movement and experimenter relationship, $F_{(1,43)}=5.07$, $p=.029$, $n_p^2=0.11$ (Figure 1). There was no main effect of experimenter relationship, $F_{(1,43)}=0.71$, $p=.404$, suggesting that the skits themselves did not affect overall amount of helping, but rather that the two skits differentially affected the amount of helping after synchronous versus asynchronous bouncing. The main effect of interpersonal movement did not reach significance.

Post-hoc independent samples t-tests were used to further investigate the interaction by assessing the effect of interpersonal movement on helping in each of the experimenter relationship conditions separately. In the "experimenter affiliation" condition, infants from the synchronous movement condition were significantly more likely than infants in the asynchronous movement condition to display helpfulness toward Experimenter 2, $t_{(21)}=3.12$, $p=.005$ (Figure 1). Infants from the synchrony condition helped 44.94% more than infants from the asynchrony condition, difference score 95% CI [14.94%, 74.94%]. In the "experimenter individuality" condition, on the other hand, there was no significant difference in the helping rates of infants in the synchronous or asynchronous movement conditions, $t_{(22)}=0.18$, $p=.857$.

To illustrate the consistency of the effect across individual participants, the number of infants in each of the four conditions who helped on more than 50% of the tasks is reported next. When assessing infant helpfulness directed toward the experimenter affiliate, 75% of infants in the synchrony condition and only 18% of infants in the asynchrony condition helped on more than half of the trials, $\chi^2(1, n = 23) = 7.46$, $p = .01$. In terms of helpfulness directed towards the experimenter demonstrating individuality, 33% of infants in the synchronous condition and 33% in the asynchronous condition helped on more than half of the trials, $\chi^2(1, n = 24) = 0$, $p = 1.0$.

Spontaneous and Delayed Helping

Similar ANOVAs were used to analyze spontaneous (within the first 10 s) and delayed (after the first 10 s) helping. There was a significant interaction between movement condition and experimenter relationship for spontaneous helping, $F_{(1,43)}=5.78$, $p=.021$, $n_p^2= .12$. As with overall helping, in the "experimenter affiliation" condition, infants from the synchronous movement condition were significantly more likely than infants in the asynchronous movement condition to display spontaneous helpfulness toward Experimenter 2, $t_{(13.9)}=2.90$ $p=.012$. Infants from the synchrony condition helped 34.34% more than infants from the asynchrony condition within the first 10 seconds of the trials, difference score 95% CI [8.83%, 59.86%]. In the "experimenter individuality" condition, there was no significant difference in the spontaneous helping rates of infants in the synchronous or asynchronous movement conditions, $t_{(22)}=-0.29$, $p=.773$.

For delayed helping, no significant main effects or interactions involving of movement condition or experimenter relationship were found. This suggests that infants not only helped the affiliate of the bouncing experimenter more following synchronous versus asynchronous movement, but that helping early in trials was especially strong.

-------------- Insert Figure 1 Here ---------------

Looking Times

An independent samples t-test revealed that there was no significant difference between total infant eye contact time with Experimenter 1 in the synchronous versus asynchronous bounce conditions, $t_{(45)}$= -1.36, p =.182. The average duration of each period of eye contact with the experimenter was calculated by measuring total time each infant spent looking at the experimenter divided by total number of glances. This measure also did not differ as a function of interpersonal movement condition, $t_{(45)}$= 0.88, p=.383. Additionally, correlations between total eye contact and total helpfulness (r = -0.06, p=.671), or average eye contact duration and total helpfulness (r = 0.13, p=.375), did not reach significance, suggesting that infants who made more direct eye contact with the experimenter during the interpersonal movement phase did not subsequently help the second experimenter more during the prosocial test phase. ANOVAs with both interpersonal movement condition and experimenter relationship as between-subject conditions also did not reveal any significant main effects or interactions on either total eye contact or gaze length (all p's > 0.26).

Discussion

The results demonstrated that 14-month-old infants who were bounced to music in synchrony with an adult experimenter were later more likely to display helpfulness (especially spontaneous helpfulness) toward a second experimenter who was shown to be affiliated with the first experimenter. On the other hand, if the two experimenters displayed individuality, synchronous compared to asynchronous bouncing with one experimenter had no effect on helpfulness towards the second experimenter. It is important to note that watching the two experimenters display affiliation or individuality had no overall effect on infants' helpfulness (i.e., no main effect of the initial skit). Infants only showed increased helpfulness to the second experimenter if the two experimenters had been shown to be "friends" *and* they were bounced in synchrony with the first experimenter.

Our previous studies showed that infants bounced in synchrony with an experimenter are subsequently more likely to help that experimenter compared to infants bounced out of synchrony with that experimenter (Cirelli et al., 2014a; 2014b). Furthermore, we showed that such behaviors are targeted at bouncing partners in that synchronous bouncing with one experimenter did not lead to increased helpfulness toward a neutral experimenter with whom the infant had not previously experienced synchronous movement (Cirelli et al., 2014b). The present experiment further elucidates effects of synchronous movement on the development of social relationships by showing that increased helpfulness after synchronous bouncing does extend to affiliates of the bouncing partner but not to people showing no specific affiliation to that person. It is also important to note that this is the first study in which the effect of synchrony on infant social behavior has been measured using a methodology in which the experimenter performing the helping tasks is completely blind to the movement condition.

The effect of synchronous movement on affiliate-directed infant helping was especially driven by increased *spontaneous* helping, paralleling the pattern of results found in previous studies measuring bounce-partner directed helping (Cirelli et al., 2014a). The experimental protocol dictates that during the first 10 s of the trial, the experimenter does not directly involve the infant in the problem and only looks at and reaches for the out-of-reach object. After this first 10 s, the experimenter makes eye contact with the infant, and eventually vocalizes about their specific need. In that regard, spontaneous helping (i.e., helping during the first 10 s) may represent a form of prosocial behavior closer to altruistic behavior, whereas delayed helping may involve compliance. Spontaneous helping may also reflect that the infant feels more involved with and attentive toward the experimenter's actions. In a study by Carpenter, Uebel and Tomasello (2013), spontaneous helping was also specifically increased in 18-month-olds who were mimicked by an experimenter, suggesting that early helping is encouraged when infants feel a connection with the recipient. The targeted effect of interpersonal synchrony on spontaneous helping may support the idea that musical engagement (which encourages interpersonal synchrony) fosters joint intentionality between actors (Kirschner & Tomasello, 2010).

In our first study (Cirelli et al., 2014a), parent ratings from the IBQ of infant willingness to approach novelty correlated with infant helping rates. In our second study (Cirelli et al., 2014b), ratings of approach and smiling correlated with helpfulness directed toward the neutral stranger, but not toward the bouncing experimenter. We hypothesized that, while infant temperament may predict helpfulness toward a neutral individual, such individual differences may be overridden by an informative interaction (such as synchronous bouncing) between a stranger and the infant. The lack of correlation between IBQ measures and helpfulness in any of the conditions in the present experiment was surprising. However, the present experiment differed from our previous experiments in that the initial skit acted like an initial familiarization phase. Perhaps this increased the familiarity of the experimenters for the infant, so that factors, such as their subsequent interpersonal movement experience, became stronger determinants of infant helpfulness compared to infants' general temperament and general willingness to approach novelty as measured by the IBQ.

Interestingly, the infants in the synchronous bouncing condition did not initiate and hold direct eye contact with the bouncer significantly more than the infants in the asynchronous condition, which would have provided support to the person-perception hypothesis. This null result may indicate that prosocial behavior following synchrony is not being driven by increased eye contact, but instead by unrelated factors such as increased perception of self-similarity, feelings of empathy, or an understanding of joint action (Kirschner & Tomasello, 2010; Valdesolo & Desteno, 2011). On the other hand, this finding may also reflect methodological limitations. Looking time is an indirect measure of attention, and so infants may increase their attention to a synchronously bouncing partner without necessarily increasing direct eye contact. We measured only direct eye contact, but it is possible that there were differences across conditions in general looking toward the experimenter. Additionally, while it is well noted that 14-month-old infants can follow gaze direction, few studies indicate that infants of this age maintain direct eye contact for prolonged period of time (Corkum & Moore, 1998; Moll & Tomasello, 2004). It should also be noted that the experimenter coding eye contact live could not be blind to the bouncing condition. As such, the hypotheses driven by the person-perception hypothesis should continue to be explored in future studies with both children and adults.

Another question of interest is the importance of the music itself for increasing prosociality. Although music, with its predictable beat, is an ideal stimulus to synchronize movements between people, it is possible that synchronous movement without music might have led to similar effects. Music does, however, have emotion regulation effects on infants (Corbeil, Trehub, & Peretz, 2015) and might still contribute positively to the infants' experience during the interpersonal movement phase. It is also not clear how the mechanisms driving prosociality following experimentally manipulated interpersonal synchrony are related to mechanisms at play during coordinated, responsive and sensitive mother-infant interactions (mother-infant synchrony), known to foster positive social outcomes (see Reyna & Pickler, 2009 for a review). It is also unknown how experiences with interpersonal synchrony might extend to influencing social cognitive outcomes in children. Thus, questions about the underlying mechanisms driving the social effects of interpersonal synchrony remain for future studies.

It should be noted that asynchrony here was defined as a tempo difference between the infant and experimenter, which is typical in studies on social effects of interpersonal synchrony. One question is whether movement at the same tempo is the crucial variable for increasing prosocial behaviour or whether movement phase is important as well. In other words, if movements between participants were phase-shifted but at the same tempo (i.e., contingent) would similar social effects emerge? In such a context, movements are at the same tempo, but do not occur at exactly the same time. One example of this is anti-phase bouncing, where one person is at the lowest point of his or her trajectory when the other is at his or her highest point, and vice versa. Indeed, we investigated the effect of anti-phase bouncing on infant helpfulness in a previous study, and found that compared to tempo-shifted asynchrony, anti-phase bouncing led to similar increases in helping behaviour as in-phase bouncing (Cirelli et al., 2014a). Thus it appears that tempo-matched (i.e., contingent) movement may be the most important determinant of social effects of movement. Still, future studies with adults using more sensitive measures of prosociality than is possible in infant studies could directly investigate whether and how phase-shifted asynchrony influences social behaviour.

The results of the present investigation may have important implications with respect to 14-month-olds' understanding of third-party relationships. Previous work has shown that infants can direct their prosociality toward 'good' social partners (Cirelli et al., 2014a; 2014b; Dunfield & Kuhlmeier, 2010; Hamlin et al., 2007; Hamlin & Wynn, 2012), and that they appear to form social expectations about third-party affiliation by at least as young as 9 months of age (Liberman et al., 2014). The present paper is the first to suggest that infants might transfer cued prosociality to the positive affiliate of a 'good' social partner. Understanding which individuals in their social environment have coalitions is an important skill to develop (Platten et el., 2010), and these findings suggest that by 14 months of age, infants may be using these skills to direct their own affiliative behaviors.

This interpretation of the social decisions being made by the infants rests on the skit manipulation. As tools implemented to study the generalizability of interpersonal synchrony's social effects, the skits that were used in this study were designed to contrast many cues to affiliation between the experimenter relationship conditions. The two skits were matched in general valence, plot, and length. However, future programs of research should investigate which specific components of these skits led to the effects found in this study. Importantly, because there was no overall main effect of experimenter relationship condition on infant helpfulness when collapsed across interpersonal movement conditions, the affiliation skit did not simply prime infants to display helpfulness indiscriminately. The affiliation skit *only* promoted increased helpfulness when it was followed by a synchronous movement experience with one of the experimenters. So infants were not simply put in a "prosocial mood" after watching the affiliation skit, which contains cooperative, synchronous, and potentially more interesting events. In that case, all infants watching the affiliation skit, regardless of movement condition, should have been more helpful than those watching the individuality skit. Rather, the interaction between movement condition and experimenter relationship suggests that infant helpfulness was determined by a combination of third-party information gained through the skit and the first-person experience of interpersonal synchrony.

In conclusion, previous studies demonstrated that infants are more likely to help an adult who previously moved in synchrony with them compared to an adult who previously moved out of synchrony with them (Cirelli et al., 2014a; 2014b), suggesting that synchronous movement helps to form positive social relationships as young as 14 months of age. In the present study we found that infants help an affiliate of a synchronously moving partner more than an affiliate of an asynchronously moving partner, but that interpersonal movement does not influence behavior toward adults showing individuality. The social effect of interpersonal synchrony only transfers to someone not involved in the movement experience if that person has behaved as an affiliate of the bouncing partner. This suggests that the positive social relationship established through synchronous movement between an infant and adult partner extends to the social group of that partner, but not to all adults in general. This study is the first to suggest that infants may transfer affiliative behaviors to "friends" of a cued social partner, suggesting that transitivity within social networks may be present in early social behavior. Overall, our findings support that interpersonal synchrony, a key component of musical behavior, is a profoundly social experience that fosters interpersonal cohesion at both the individual and group levels, and does so early in development.

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Supplementary Information

Experimenter Affiliation Skit

(Experimenter 1 walks into the sound booth, swinging arms enthusiastically.)

Experimenter 1 = E1

Experimenter 2 = E2

E2: Hi _____________! *(insert E1name here)*

E1: __________! *(insert E2 name here)* Hi!

(They hug.)

E2: *(bringing hands to shoulder level)* How are you today? Ready to play some games?

E1: Oh! Yes! *(bringing hands to heart)* I love games!

E2: *(mimicking the E1)* Me too!

E1: I am always ready to play games! What games will we be playing today?

E2: Hmmmm... Well, I'll be drawing a picture and you will be playing the bouncing game.

E1: Yay! *(bouncing)* The bouncing game is my favourite! Do we have all of the stuff we need?

E2: Oh yes! Everything is right over there *(points to where the equipment is located)* No, wait! *(grabs her head)* I forgot to wear my thinking cap this morning! How can I play games without my thinking cap?!

E1: *(grabbing her head in the same way)* Oh no! I also forgot to wear my thinking cap! I can't believe it! I never go anywhere without my cap! It keeps all of my good ideas inside my head! What should we do?

E2: *(bringing finger to chin)* Hmmm... Let me think.

E1: *(mimicking E2)* Hmmm...

E2: *(putting finger in the air)* I know! I just remembered! We keep spare thinking caps in the sound booth! The only problem is that I don't know where they're hiding...

E1: That's okay! *(looking around)* The room isn't very big. Lets take a look and see if we can find them.

(The girls start searching the room for thinking caps. They each find one behind speakers at opposite ends of the booth)

E1: Look! I found a thinking cap behind this speaker!

E2: Yay! I found one too!

(They bring their thinking caps to the centre of the booth, where they can be seen clearly by the infant. Silently, they place their thinking caps on their heads. They both put their caps on sideways. The girls stand back, hands on hips, to observer the other)

E1: *(pointing at E2 then at her own head)* You wear your cap the same way that I do. Have you always worn your cap that way?

E2: Oh yes, I have always worn my thinking cap this way, ever since I was little. How about you?

E1: Well... sometimes I like to wear it like this, when I am outside and there is lots of sunshine! *(switches her hat around so that flap is over her eyes)*

E2: Oh! Neat! Let me try! *(switches her cap)* Oh yes! I can see how this would this flap would shield my eyes. This is fun! I wonder if there are other ways to wear thinking caps!

E1: Let's try!

(E1 and IGM take turns suggesting new cap styles. Once one person illustrates a style, the other tests it out. After them backwards and then sideways in the opposite direction, they return the hats to their original sideways position.)

E2: There! That feels better! *(places hands on hips)*

E1: *(placing hands on hips)* Just the way I like it.

E2: Well, this has been fun! But, now that I have my thinking cap, I should probably set up those games.

E1: Good idea! I should get the bouncing game ready!

E2: Good idea, _______! *(insert E1's name)* I'll see you later!

(They hug again.)

E2: *(as she is leaving)* See you later, __________! *(insert baby's name)*

Experimenter Individuality Skit

(Experimenter 1 walks into the sound booth, swinging arms enthusiastically. Experimenter 2 waits in the soundbooth, standing stage left)

Experimenter 1 = E1

Experimenter 2 = E2

Experimenter 1's monologue. *(During this monologue, E2 stands stage left, facing the 'audience', E2 watches as E1 enters the booth, then looks away. She watches periodically when E1 speaks, but does not engage with her)*

E1: *(standing stage right, facing the 'audience')*

Okaaay! Now it is time to get ready for the bouncing game! I am so excited – I love the bouncing game! *(She bounces)*

Hmmm… *(brings hands to hips)*

I wonder... Do we have all the stuff that we need? *(nods)*

Let's see… Steph is wearing the carrier, the headphones are right over there *(points)*…

No! Wait! *(brings hands abruptly to her head)*

I forgot to wear my thinking cap today! This is terrible! I can't play the bouncing game without my thinking cap! What should I do? Hmmm.. *(pauses, then brings her right pointer finger up to eye level)*

Oh! Yes! I just remembered! There are spare thinking caps hiding somewhere in the sound booth. I'll just look for one of those. *(She starts searching the booth and finds a thinking cap behind the speaker on stage right)*

Ah! A thinking cap! *(She walks back to the centre of the sound booth)*

Great. I'll just put it on, so that I can start thinking clearly… *(places cap on her head with the flap pointing to the right, then places hands on her hips)*

Hmmm. This doesn't quite feel right. Oh! I know why! Maybe if I put it on the other way… *(rotates the hat so that the flap is over her left ear.)*

Aw, yes. Much better. *(gets lost in thought)*

Experimenter 2's monologue. *(During this monologue, E1 stays stage right, facing the 'audience'. E1 watches periodically when E2 speaks, but does not engage with her)*

E2: Great! We have here everything that we need to play the marker, clothespin and paper ball games. *(pauses, doubting herself)*

Hmm… Perhaps I should go through my list one last time… We have a clothesline. Check. *(points at clothesline)*

We have a desk. Check. *(points at desk)*

We have clothespins. Check. *(points at clothespins)*

Yes. Everything seems to be in order. But, brrrrr… *(grasping her arms)*

It is so cold in this sound booth! I really wish that I had a scarf to keep me warm. Hmm… *(brings arms up in a questioning manner)*

I wonder if there might be a spare scarf lying around here somewhere. *(She looks around and finds a scarf hidden in the back of the soundbooth)*

Oh! What luck! A scarf! This should keep me nice and cozy! (returns to her spot stage left, then *wraps* the scarf around her neck)

Oh yes, nice and cozy! *(smiling and hugging herself)*

But, not so chic... I wonder... if I drape the scarf over my shoulders like this... *(rearranges the scarf so that it acts more like a shawl)*

I can be both warm and stylish at the same time! Excellent! It is time to get this show on the road! See you later, __________! (insert baby's name)

Tables

Table 1: *Roles of each experimenter in the three phases of the experiment*

Experimenter	**Familiarization Phase**	**Interpersonal Movement Phase**	**Prosocial Test Phase**
Assistant	Sits with parent	Holds and bounces baby	Leaves the room
E1	Performs skit	Faces baby and bounces	Leaves the room
E2	Performs skit	Leaves the room	Performs the three helping tasks

Figures

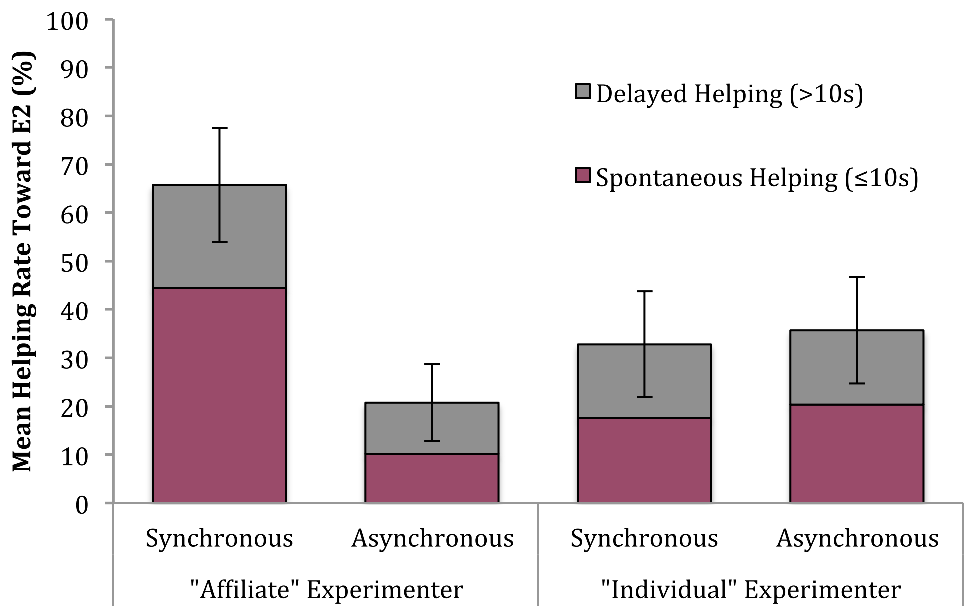

Figure 1: Overall mean infant helpfulness (mean % of trials on which infants helped) toward Experimenter 2 from the four between-subjects conditions. Spontaneous helping (helping within the first 10 seconds of the trial) and delayed helping (helping later than 10 seconds into the trial) are both shown. When Experimenters 1 and 2 were affiliates, infants who had previously moved synchronously with Experimenter 1 were significantly more helpful when interacting with Experimenter 2 than infants who had previously moved asynchronously with Experimenter 1. However, when Experimenters 1 and 2 behaved individually, there was no difference in helpfulness toward Experimenter 2 as a function of the movement condition with Experimenter 1. These effects are especially apparent with spontaneous helping. Error bars represent standard error of the mean for overall mean infant helpfulness.

CHAPTER 5: Effects of interpersonal movement synchrony on infant helping behaviors: Is music necessary?

Cirelli, L. K., Wan, S. J., Spinelli, C. & Trainor, L. J. (in press). Effects of interpersonal movement synchrony on infant helping behaviors: Is music necessary? *Music Perception.*

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Preface

In the previous chapters, I found that interpersonal synchrony encourages infant helpfulness. I found that this boost in infant helping following synchronous compared to asynchronous interpersonal movement is directed to their movement partner, and members of that person's social group, but does not extend to encouraging helpfulness directed toward a neutral stranger with no affiliation to the movement partner. In all of these experiments, the presence of background music was held constant. In Chapter 5, I investigate whether synchronous compared to asynchronous movement in a non-musical context still encourages infant helpfulness. Results show that, indeed, infants are more helpful following synchronous compared to asynchronous movement, even when no background music was present during the interpersonal movement phase. I also found interesting differences in helping in Chapter 5 compared to Chapters 2-4. Infants helped less overall, helped later in the helping trials, and were also more likely to become extremely fussy during the interpersonal movement phase. I conclude from this study that music may not be necessary for interpersonal synchrony to encourage infant helpfulness, but it may provide an emotion-regulating context within which interpersonal synchrony can be naturally achieved.

Abstract

Moving in synchrony with others encourages prosocial behavior. Adults who walk, sing, or tap together are later more likely to be cooperative, helpful, and rate each other as likeable. Our previous studies demonstrated that interpersonal synchrony encourages helpfulness even in 14-month-old infants. However, in those studies, infants always experienced interpersonal synchrony in a musical context. Here we investigated whether synchronous movement in a non-musical context has similar effects on infant helpfulness. 14-month-olds were held and bounced gently while the experimenter faced the infant and bounced with them either in- or out-of-synchrony. In contrast to our previous studies, instead of listening to music during this interpersonal movement phase while being bounced, infants listened to non-rhythmic nature sounds. We then tested infant prosociality directed toward the experimenter. Results showed that synchronous bouncing still encouraged more prosociality than asynchronous bouncing, despite the absence of music. However, helping was more delayed and fussiness rates were much higher than in our previous studies with music. Thus music may not be necessary for interpersonal synchrony to influence infant helpfulness, but the presence of music may act as a mood regulator or distractor to help keep infants happy and allow them to fully experience the effects of synchronous movement.

Introduction

Moving in time with others, or interpersonal synchrony, has social consequences. When adults walk, row, tap, dance, or sing in synchrony with one another, affiliative behaviors such as trust, cooperation, and ratings of likeability are encouraged (Anshel & Kipper, 1988; Hove & Risen, 2009; Reddish, Fischer & Bulbulia, 2013; Tarr, Launay, Cohen & Dunbar, 2015; Valdesolo, Ouyang, & DesSteno, 2010; Weinstein, Launay, Pearce, Dunbar & Stewart, 2015; Wiltermuth & Heath, 2009). Even 4-year-old children who play together in a musical versus a non-musical way are later more helpful and cooperative with one another (Kirschner & Tomasello, 2010). Also, children with poor prosocial skills who took part in weekly group music classes encouraging high levels of interpersonal synchrony, showed larger boosts in self-reported sympathy and prosociality compared to controls (Schellenberg, Corrigall, Dys & Malti, 2015).

This effect of synchronous movement on social behaviour has been shown to even influence infants. For example, 12-month-old infants are more likely to show a social preference for a synchronously- over an asynchronously-rocking animate toy in a non-musical context (Tunçgenç, Cohen & Fawcett, 2015). Furthermore, work in our laboratory has shown that interpersonal synchrony in a musical context actually encourages directed prosociality in 14-month-old infants (Cirelli, Einarson & Trainor, 2014; Cirelli, Wan & Trainor, 2014; Cirelli, Wan & Trainor, 2016; Trainor & Cirelli, 2015). In these studies, infants were held in a baby carrier worn by an assistant, facing an experimenter. The assistant bounced them to the beat of a background song, “Twist and Shout” by the Beatles. At the same time, the experimenter facing the infant either bounced in synchrony with how the infant was bounced, or out-of-synchrony (i.e. at a different tempo). Infants then performed instrumental helping tasks with that experimenter, during which the experimenter “accidentally” dropped objects that she was using to complete simple tasks. These tests of prosocial behavior were developed by Warneken and Tomasello (2006; 2007). On each trial, infants had a 30 s window in which to respond. During the first 10 s, the experimenter focused only on the dropped object. During the remaining 20 s, the experimenter involved the infant in the problem by alternating her gaze between the infant and object, and eventually naming the object. Infants who had been bounced synchronously handed back significantly more dropped objects than infants who had been bounced asynchronously (Cirelli et al., 2014a). Furthermore, infants who had been bounced synchronously helped more than asynchronously bounced infants particularly during the first 10 s of the 30 s response window in each trial. Helping in the first 10 s is considered “spontaneous” helping, because during this period the experimenter focuses only on the object. After the first 10 s, the infant is given social cues (e.g., the experimenter looks at the infant and the object) so helping during this period may reflect compliance as well as prosociality. An increase in spontaneous helping is interpreted as increased altruistic helping rather than compliance (Carpenter, Uebel, & Tomasello, 2013; Cirelli et al., 2014a).

A subsequent study replicated the effect of synchronous movement on infants' helping behavior and extended the finding by demonstrating that bouncing synchronously compared to asynchronously with one experimenter does not influence helpfulness directed toward a neutral experimenter uninvolved in the bouncing experience (Cirelli et al., 2014b). However, in a third study, infants did extend their helpfulness towards a second experimenter, but only if this person was shown to be socially affiliated with the experimenter with whom the infant had been bounced synchronously (Cirelli et al., 2016; Trainor & Cirelli, 2015). This suggests that infants may use synchronous movement as a cue for social relationships. This third study is also important in that the second experimenter, with whom the infants performed the prosocial tasks, was blind to whether the infant experienced synchronous or asynchronous bouncing. In this study, we also found that the amount of time infants spent making direct eye contact with the bouncing experimenter during the interpersonal movement phase did not differ across movement condition (synchronous/asynchronous) and did not predict helping (Cirelli et al., 2016). In sum, these three studies show that synchronous movement can have profound effects on social affiliation early in development.

Our previous investigations of prosociality in 14-month-olds following interpersonal synchrony occurred in a musical context. The music heard by the infant was always present. The high predictability of musical beats in general (e.g., see Repp, 2006) makes music a very good context for synchronizing movements. However, whether music itself contributed to the increased prosociality observed in our previous studies, or whether synchronous movement in a non-musical context leads to similar rates of infant helping could not be addressed in these previous experiments.

The social effects of interpersonal synchrony have been explored in both musical and non-musical contexts. In musical contexts, adults who sing together later rate each other as more trustworthy (Anshel & Kipper, 1988), are more cooperative (Wiltermuth & Heath, 2009), experience increased pain thresholds (a proxy for endorphin release), and experience feelings of enhanced group cohesion (Weinstein et al., 2015). Similar results are seen when adults dance together in synchrony. After this experience, they are more cooperative (Reddish et al., 2013), can remember more visual details about one another (Woolhouse, Tidhar & Cross, 2016), experience increased pain thresholds, and have greater feelings of group cohesion (Tarr et al., 2015) compared to those dancing out-of-synchrony.

Affiliative effects have also been observed following interpersonal synchrony in non-musical contexts. In the experiment by Tunçgenc and colleagues (2015) with 12-month-old infants, it was found that synchronous movement in a non-musical context influenced infant preferential reaching. In adults, increased pain thresholds are found following rowing synchronously with others versus alone (Cohen, Ejsmond-Frey, Knight & Dunbar, 2010). Cooperation is encouraged by walking synchronously versus asynchronously (Wiltermuth & Heath, 2009). Individuals who tap their fingers to an even pace matched by an experimenter later rate the experimenter as more likable compared to those who tap asynchronously (Hove & Risen, 2009). Action coordination was found to be more successful between individuals after they rocked in chairs synchronously versus asynchronously (Valdesolo et al., 2010). These studies demonstrate that interpersonal synchrony has social benefits even in non-musical contexts.

Although the prosocial benefits of interpersonal synchrony have been shown even in the absence of music, engaging synchronously with others in a musical context may still be qualitatively different from interpersonal synchrony in a non-musical context. More specifically, the presence of music may provide additional emotional benefits. There is evidence that in adults, music listening can reduce cortisol levels (Fukui & Yamashita, 2002) and increase opiate receptor expression (Stefano, Zhu, Cadet, Salamon & Mantione, 2004), both physiological markers of stress reduction. Demos and colleagues (2012) reported that feelings of closeness between two participants was better predicted by how strongly each participant's movements were coupled to background music rather than to one another. These results highlight that moving to music in the presence of another person may encourage feelings of sharing an experience with that person, which may be more important than the actual degree of synchrony.

In infants, musical context may also contribute positively to social and emotional behaviour. Infant-directed singing, for example, delays distress in 7- to 10-month-olds separated from their parent (Corbeil, Trehub & Peretz, 2015). Infants were placed in a sound booth with the parent sitting out of sight. Using a between-subjects design, infants listened to infant-directed speech, adult-directed speech or infant-directed singing over loudspeakers. Infants in the infant-directed singing condition lasted more than twice as long before displaying distress compared to infants in either of the speech conditions (Corbeil et al., 2015). In a related study, Trehub, Ghazban and Corbeil (2015) reported that mothers soothed their distressed 10-month-old infants more quickly and reduced infant arousal when using singing versus speech. Musical intervention has also been successful in reducing bouts of inconsolable crying in premature hospitalized infants (Keith, Russell, & Weaver, 2009). Together, these studies suggest that music may be a useful mood-regulator or distractor for distressed infants. This mood-regulation effect may be an important component of musical engagement that contributes positively to infants' experiences in addition to the contribution of interpersonal synchrony.

In the present study, we investigate whether interpersonal synchrony versus asynchrony in a non-musical context promotes helpfulness in 14-month-old infants. The effect of synchrony on infant preferential reaching in a non-music context (Tunçgenc et al., 2015) supports our hypothesis that synchronous movement in a non-musical context will also influence infant helping, which is a much more cognitively demanding and complex social behaviour. We are also interested in qualitative differences in infant helping following non-musical synchrony using a methodology that has already been used in a musical context.

To test our questions, infants participated in two experimental phases: 1) an interpersonal movement phase, during which an assistant held the infant and bounced him/her gently at a constant rate with nature sounds playing in the background, while an experimenter facing the infant bounced at either the same or at a faster rate, and 2) the prosocial test phase, during which the infant was given the opportunity to hand accidentally dropped objects back to the experimenter, who needed them to complete a task. The procedure and participant sample closely matches those used by Cirelli and colleagues (2014a; 2014b; 2016). The critical difference is that instead of listening to music during the interpersonal movement phase, infants listened to non-rhythmic nature sounds (such as rushing water, wind-rustled leaves). We hypothesized that interpersonal synchrony in such a non-musical context would still encourage prosociality. We were further interested in whether infants' experiences differed in any way from those in our previous studies where infants were bounced to music in the interpersonal synchrony phase.

Method

Participants

40 walking infants (22 girls; *M* age=14.6 months; SD = 0.4 months) were recruited using the Developmental Studies Database at McMaster University. Of these 40 infants, 40% (16 infants, 10 girls) did not complete the procedure due to excessive fussiness. Of these babies, 5 were too fussy when placed in the carrier to even begin bouncing, 8 were bounced in the synchrony condition and 3 in the asynchrony condition but become too fussy to continue before the bouncing phase ended. Fussy babies were replaced so that 12 babies (gender balanced) completed

each condition (synchrony, asynchrony). The average age of these remaining 24 infants was 14.6 months, SD = 0.3 months. The McMaster Research Ethics Board (MREB) approved all experimental procedures. Informed consent was obtained from all parents.

Procedure

Phase 1: Interpersonal movement phase. When infants arrived at the laboratory with their parent(s), the experimenter obtained parental consent and asked parents to fill out a demographics questionnaire as well as three scales (approach, smiling, and activity) from the Infant Behavior Questionnaire (Rothbart, 1981). The assistant, who would later be holding the infant, interacted with the child and introduced him/her to the objects that would later be used during the prosocial test phase (i.e. a clothespin, a marker, and a crumpled paper ball).

Everyone then moved into the sound-attenuating chamber where the experiment itself would take place. The parent was asked to help place the infant in the carrier (Infantino Flip 2012 Infantino LLC) worn by the assistant, so that the infant faced outwards. The parent(s) then sat on a chair in the corner, out of the infant's line of sight. The experimenter stood facing the assistant and infant, about 4.5 feet away.

The experimenter held a button box, and triggered the start of the interpersonal movement phase via a button press connected to Presentation software running on a Windows XP computer. This program initiated 140-s of stimulus presentation. During this phase, infants listened to a 140-s recording of nature sounds (rushing waters, wind-rustled leaves) compiled on an open-source sound mixing website (naturesoundsfor.me). These nature sounds were played through a Denon amplifier (PMA-480R) connected to an audiological loudspeaker (GSI) 6.5 feet from the right side of the infant.

During this phase, the experimenter and assistant holding the infant listened to "bounce instruction tracks" through Denon AH-D501 headphones. These instruction tracks contained woodblock sounds overlaid on pink noise. The assistant and experimenter were trained to bounce by bending at the knees with their feet firmly on the ground so that the lowest part of their bounce lined up with the woodblock sound. In the synchronous condition, both the assistant and experimenter listened to the "bounce instruction track" at 50 beats per minute (bpm). In the asynchrony conditions, the assistant listened to the 50 bpm track while the experimenter facing the baby listened to it at 70 bpm, so that her movements were faster. Infants were randomly assigned to one of these two movement conditions before arriving at the laboratory. Gender was counterbalanced across conditions. These rates of bouncing match those used in our previous experiments (Cirelli et al., 2014b; Cirelli et al., under revision). Our original experiment (Cirelli et al., 2014a) used both faster and slower bouncing for different infants in the asynchrony condition. Since no differences were found between infants bounced faster versus slower, in the present experiment we used only faster bouncing by the experimenter in the asynchronous condition. The experimenter facing the baby was instructed to smile at the infant and try to make direct eye contact throughout the interpersonal movement phase.

Phase 2: Prosocial test phase. Once the interpersonal movement phase ended, the infant was taken out of the carrier and the assistant left the room. The experimenter now performed three instrumental helping tasks (3 trials in each task) with the infant. These tasks were developed by Warneken and Tomasello (2006; 2007) and have been used in our previous studies on infant social behavior following interpersonal synchrony (Cirelli et al., 2014a; 2014b; under revision).

The three tasks consisted of 1) the clothespin task, during which the experimenter pinned dishcloths onto a small clothesline using plastic clothespins, 2) the marker task, during which the experimenter used different colored markers to draw a picture of a flower on a 2.5-ft high table, and 3) the paper ball task, during which the experimenter threw paper balls from a jar into a bucket that was placed on a 2.5-ft high table. The order of the three tasks was counterbalanced across gender and movement condition. Each task began with the experimenter successfully demonstrating the goal once (e.g. successfully pinning up the first corner of the dishcloth). Then, the test trials began.

During each of the nine test trials, the experimenter dropped the object (a clothespin, a capped marker, or a paper ball) that was being used to complete the task. She then reached for the object for 30-seconds. During the first 10 seconds, the experimenter focused her gaze only on the object. During the next 10 seconds, she alternated her gaze between the object and the infant. During the final 10 seconds, she continued to alternate her gaze between the object and the infant, and also vocalized the objects name (e.g. "My clothespin!"). The trial ended either when 30-seconds had elapsed, or when the infant picked up and handed the object back. The experimenter then successfully used either the retrieved object (if it had been handed back) or an alternate object to complete her task before progressing onto the next trial or task.

Data coding

Two mounted cameras (a Canon PowerShot SD1000 and a GoPro HERO3+) recorded the experimental procedures, and these videos were later used to code helpfulness. There were two raters, each blind to infants' interpersonal movement condition while coding. Raters viewed the tapes and recorded whether infants handed back the objects on each of the 9 trials. Infants received 1-point for handing the objects back within the 30-second trial window, and received 0.5-points for handing the objects back after the 30-second window had ended but before the next task began. Overall helping rate was calculated as (score[task 1] + score[task2] + score[task 3]) / (3 tasks X 3 trials) X 100%. The time it took infants to hand objects back was also recorded, and used to calculate a separate score for spontaneous helping (helping within the first 10 seconds of the trial) and delayed helping (helping after the first 10 seconds). Inter-rater reliability was high, r=0.99, p<.001.

In order to examine the consistency of the experimenter's behaviour across conditions, two separate raters blind to the hypotheses and conditions watched videos showing only the bouncing experimenter (assistant and infant were cropped out) during the interpersonal movement phase. 30 s clips of this experimenter, starting 60 s into each infant's interpersonal movement phase, were shown to the raters. These raters were instructed to watch each video and then, using 10-point Likert scales, rate how happy, smiley, attentive, interactive, and connected to her bounce partner this experimenter seemed. These raters also answered a forced-choice question asking if the experimenter in each video was bouncing in synchrony or out-of-synchrony with the out-of-view bounce partner. Neither rater rated experimenter behaviour differently across the two movement conditions on any of the scales (all p's >.241). In addition, neither rater was able to correctly identifying the movement condition at a level above chance (p=.840 for both raters). This supports our assumption that experimenter behaviour was consistent across interpersonal movement conditions.

Results

Using a predetermined z-score outlier cut-off of ±2 for overall helping rate, one infant (a female in the asynchrony condition) was excluded from the analysis as an outlier[3]. No significant correlations were found between infant overall helpfulness or early or late helpfulness and parent-rated IBQ scores on smiling, activity, or approachability (all p's > 0.383). There was no main effect of task

[3] Given the large between-subjects variability in this measure of infant helping, this predetermined outlier cut-off is often used in our lab. When this infant is included in the analyses, overall helping differences across movement conditions do not quite reach significance, p=.12, but statistical decisions about delayed/spontaneous helping differences across movement condition remain unchanged.

(clothespin, marker, paperball) on overall helping rate (p=.771), and so tasks were collapsed in the following analyses. Task and overall means across bounce conditions are shown in Table 1.

--------------------------- Insert Table 1 Here -------------------------------------

Overall Helping

An independent samples t-test was used to compare overall helping rates across the two movement conditions (synchrony/asynchrony). Infants bounced synchronously with the experimenter handed back significantly more objects than infants bounced asynchronously with the experimenter (44.6%>14.6%), $t_{(21)}$=2.33, p=.03, d=1.02 (See Figure 1). Infants from the synchrony condition helped 29.86% more than infants from the asynchrony condition, difference score 95% CI [3.21%, 56.52%].

To illustrate the consistency of this effect across individual participants, the number of infants in each of the two movement conditions who helped on more than 50% of the trials was calculated. For the synchrony condition, 58% of infants helped on more than half of trials, while for the asynchrony condition, only 9% of infants helped on more than half of trials, $\chi^2(1, N=23)=6.14$, p=.027.

Spontaneous and Delayed Helping

Independent samples t-tests were used to compare helping rates for both spontaneous (within the first 10 s) helping and delayed (between 11 and 30 s) helping across movement conditions. There was no effect of movement condition on spontaneous helping, $t_{(21)}$=.87, p=.395. However, there was a strong effect of movement condition on delayed helping, $t_{(16.44)}$=3.20, p=.005, d=1.58 (See Figure 1). Infants from the synchrony condition displayed delayed helping on M=25.83% of the trials, while infants from the asynchrony condition displayed delayed helping on only M=4.55% of trials, difference score 95% CI [7.05%, 35.53%]. This suggests that the effect of movement condition on overall helping is specifically driven by a boost in delayed helping following interpersonal synchrony. Infants in the synchrony condition helped the experimenter significantly more than infants in the asynchrony condition, but the increased helping took place late in the trials.

Fussiness Rates

There was a surprisingly high fussiness rate in this experiment. Out of the 40 infants who came in for testing, 16 (or 40%) of them were too distressed to complete the interpersonal movement phase. This rate is surprisingly high compared to the rates in our previous studies (17% in Cirelli et al., 2014a; 25% in Cirelli et al., 2014b; 16% in Cirelli et al, under revision). Parent-rated IBQ scores for the infants who made it through the experiment versus those who were too fussy to continue did not differ for composite scores of smiling ($t_{(37)}$=0.52, p=.604), approach ($t_{(37)}$=1.97, p=.28) or activity ($t_{(37)}$=3.52, p=.727). However, the response to one particularly relevant question ("When introduced to a strange person, how often did the baby cling to a parent?") did differ across these two groups, $t_{(37)}$=2.07, p=.046, d=0.68. Infants who made it through the experiment were rated on a scale of 1 to 7 as being less likely to cling to a parent (median score = 4; "About half the time") than infants who were too fussy to continue (median score = 6; "Almost always"). It should be noted that parents fill out the IBQ during or after the procedure, so how the infant responded to the experimenters might have influenced parent responses. However, parents were instructed to respond based on how infants have behaved in the past week.

Discussion

These results demonstrate that 14-month-old infants display more helpfulness towards a synchronously moving partner compared to an asynchronously moving partner, even in a non-musical context. This suggests that the effect of interpersonal synchrony on infant helping is not a music-specific effect, even early in development. This is in line with the findings on infant preferential reaching by Tunçgenc et al. (2015). At the same time, we found interesting differences between the results in the present study and results from previous studies where general procedures were very similar except for the presence of music during the initial interpersonal movement phase. First, the effect on overall helpfulness in this sample was specifically driven by a boost in delayed helping (helping after 10 seconds into each trial). In our previous studies (Cirelli et al., 2014a; Cirelli et al., 2016), it was spontaneous helping (helping within the first 10 s) that was especially increased by interpersonal synchrony. Spontaneous helping has been interpreted as representing more altruistic helpfulness (Cirelli et al., 2014a; Carpenter et al., 2013). This, along with the surprisingly high drop out rate due to fussiness in the current sample (40%), suggests that infants were overall more distressed when listening to environmental sounds during the bouncing than those who had been bounced in a musical context. Considering the fact that music has been found to delay fussiness and regulate infant mood (Corbeil et al., 2015), we interpret our late helping rates and higher fussiness rates as evidence that infants were less content in the present experiment than they were in our previous studies.

The high fussiness rate in the present sample (40%) also makes it difficult to directly compare helpfulness rates to those recorded in our previous studies. While that the population of infants recruited for this experiment match those of our previous experiments, it is likely that infants who actually *complete* the procedure in the present study are qualitatively different from in our previous studies due to the high fussiness rate. More specifically, because of the high fussiness rate, one might have predicted that since only the infants who were rated as less likely to cling to their parent made it through the experimental procedure, helping rates would have been artificially inflated. Surprisingly, however, overall helping rates were numerically lower than in our previous samples. The previous samples came from the same participant pool, infants were of the same age as in the current study, sample sizes per condition were the same, and procedures were very similar. In the present study, helping rates following interpersonal synchrony averaged 44.6%. We found higher rates in our previous studies (50.6%, 61.3% and 65.67% respectively for Cirelli et al., 2014a; 2014b; and 2016). These lower helping rates, especially from a sample rated to show less parental clinginess, are consistent with our interpretation that infants were less content in the present study than in our previous studies involving music.

The way that interpersonal synchrony encourages prosociality is still a matter of debate. Some scholars suggest that our attention is directed towards those who move in synchrony with us, and that by attending to and learning more about these individuals we feel more comfortable with them (Macrae, Duffy, Miles & Lawrence, 2008; Woolhouse et al., 2016). Others suggest that interpersonal synchrony leads to an overlap in our perception of self and other. This overlap increases perception of self-similarity and encourages feelings of empathy (Overy & Molnar-Szakacs, 2009; Valdesolo & DeSteno, 2011). It has also been proposed that neurohormonal mechanisms are at play, and that interpersonal synchrony triggers the release of oxytocin and/or endorphins, both related to social bonding (Freeman, 2000; Tarr, Launay & Dunbar, 2014). While the present study does not attempt to disentangle these proposed mechanisms, it does highlight the importance of considering the socioemotional consequences, both cognitive and neurohormonal, of interpersonal synchrony and musical engagement as having separate but potentially interactive effects.

In sum, these results suggest that infants direct helpfulness towards synchronously moving partners, even in a non-musical context. However, without music, infants are less content and are slower to display this helping behavior. This supports the idea that while music may not be necessary for the increased prosocial effect of synchronous movement, music acts as a mood regulator or distraction from distress.

Music also creates a natural context in which interpersonal synchrony can be achieved with others (in the present experiment, movement synchrony was achieved by the artificial means of having the assistant and experimenter listen to a beat track on headphones) because of our propensity to move to the underlying beat in music (for example, see Patel & Iversen, 2014; Repp, 2006; van der Steen & Keller, 2013; Trainor, 2015). When individuals in a group all align their movements with the underlying beats in the same piece of music, they end up aligning their movements with one another by default. Therefore, musical contexts create a setting within which interpersonal synchrony is easily achieved, and where mood-enhancing effects of music may complement and contribute to the social benefits of interpersonal synchrony. This combination of providing a context that fosters 1) social bonding and 2) emotional regulation may explain why music is a special and important social tool. This is likely why musical behaviors such as singing and dancing are present in social situations in which the goal is to feel affiliated with others, such as at parties, religious ceremonies, weddings, funerals, and in the military. The present study shows that even early in development, both synchronous movement and music contribute to prosocial behavior and interpersonal affiliation.

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Author Note

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Tables

Table 1
Objects Handed to Experimenter (Helping) Across Tasks and Bounce Conditions

Movement Condition	Clothespin	Paper Ball	Marker	Total Helping
Asynchronous	0.50 (0.34)	0.45 (0.31)	0.36 (0.28)	1.32 (0.75)
Synchronous	1.42 (0.32)	1.13 (0.37)	1.46 (0.40)	4.00 (0.86)

Note. Average number of objects handed back is reported here, with SEM shown in parentheses. Maximum score for individual tasks is 3 objects. Maximum score for total helping is 9 objects.

Figures

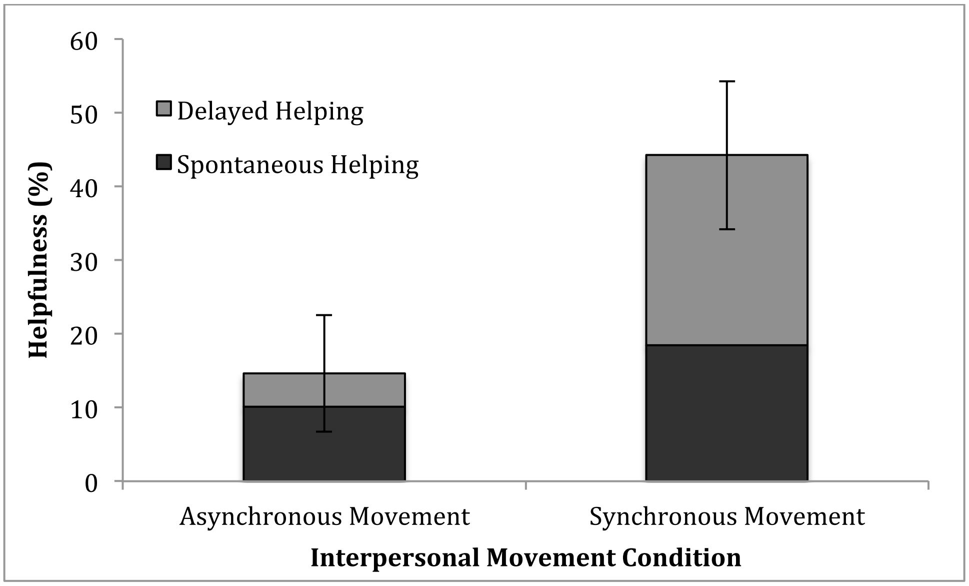

Figure 1: The average percentage of objects handed back to the experimenter as a measure of helpfulness (± SEM of overall helping). From this graph, overall helping, spontaneous helping (within first 10 seconds of trial) and delayed helping (after first 10 seconds of trial) can be seen. Infants from the synchronous movement condition helped significantly more overall than infants in the asynchronous movement condition. This was specifically driven by a boost in delayed helping following interpersonal synchrony (no effect of spontaneous helping).

CHAPTER 6: General Discussion

Main Findings and Unique Contributions

In this thesis, I examined how interpersonal synchrony influences 14-month-old infants' tendency to help adults. The prosocial effects of interpersonal synchrony were previously documented with adult populations, but I am the first to investigate this effect in early development. In Chapter 2, I designed a novel methodology to investigate how interpersonal synchrony between 14-month-olds and an adult experimenter affects infants' helping. In Chapter 2, Experiment 1, I found that infants were more likely to help a synchronously- compared to an asynchronously-moving partner, and were especially likely to display this increased helpfulness within the first 10 s of the 30 s helping trial.

Chapter 2 is the first investigation to carefully manipulate interpersonal synchrony with a non-adult population. Prior to this research, Kirschner and Tomasello (2010) found that musical compared to non-musical play between pairs of 4-year-olds encouraged helpfulness and cooperation, but isolating interpersonal synchrony from other aspects of musical play was beyond the scope of this investigation. Building off of our published work, Tunçgenc and colleagues (2015) recently documented that 12-month-old (but not 9-month-old) infants prefer to reach for a synchronously- compared to an asynchronously-moving teddy bear. These interesting findings fit well with our results showing that slightly older infants will direct complex prosocial behaviour (i.e. helping) toward social partners with whom they have experienced synchronous movement.

Chapter 2 also provides the first study to show that infants this young help certain social partners over others, depending on their prior social experience with these individuals. Previous work on infant helpfulness has primarily documented whether infants will help at all (Warneken & Tomasello, 2006; 2007), whether this helpfulness is driven by concern for the experimenter's wellbeing (Hepach, Vaish, & Tomasello, 2012), and whether infants help even if they must disengage from an exciting game to do so (Warneken & Tomasello, 2013). In these experiments, the actions of the experimenter have never been systematically manipulated to vary how infants evaluate this person. The only experiment to investigate selective helping did so with much older infants, 21-month-olds (Dunfield & Kuhlmeier, 2010). In this study, one experimenter tried but failed to give the child a toy. The second experimenter pretended to give the child a toy, but then, teasingly, pulled it away. Later, when both experimenters reached for a dropped toy, the infants were significantly more likely to hand it back to the 'nice' experimenter instead of the 'mean' experimenter (Dunfield & Kuhlmeier, 2010). The results of Chapter 2 show that much younger infants (14-month-olds) are also more likely to help certain social partners (synchronous movers) over others (asynchronous movers). Such selective helping supports the "partner choice" model of human prosociality, which suggests that directing prosociality toward "better" social partners is an adaptive strategy, as it increases the likelihood of reciprocity (Kuhlmeier, Dunfield & Neill, 2014).

In Chapter 2, Experiment 1, the main effect of synchrony on helping was not qualified by a main effect of beat predictability or an interaction with beat predictability. This suggests that, at least with this age group, interpersonally synchronous movements can either be predictable (e.g. isochronous) or unpredictable (e.g. randomized) and will still encourage more helpfulness than interpersonally asynchronous movements. This is the first investigation to address whether synchronous interpersonal movements must be predictable for social effects to emerge.

In Chapter 2, Experiment 2, I also investigated how infant helping is influenced by antiphase bouncing (moving at the same tempo, but with one person at the highest part of their bounce and the other at the lowest and vice versa). I found that like synchronous movement, antiphase movement also leads to increased infant helping compared to asynchronous movement, suggesting that it may be contingency in interpersonal movement (i.e. moving at the same moment in time) rather than mirroring in interpersonal movement (i.e. moving in the exact same way at the same moment in time) that drives these social effects.

In Chapter 3, I investigated whether this boost in infant helpfulness following synchronous compared to asynchronous movement was the result of primed (generalized) helpfulness or cued (directed) helpfulness. To test this, I measured how much infants helped both their movement partner (synchronous or asynchronous) and a neutral stranger uninvolved in the movement experience. Replicating the results of Chapter 2, we found that infants in the synchronous movement condition helped the experimenter more than infants in the asynchronous movement condition. However, this movement manipulation did not affect helpfulness directed toward a neutral stranger. These results suggest that synchronous movement does not simply put infants into a generally helpful mood, in which case they would also help the neutral stranger more after synchronous movement. Instead, it seems to specifically cue prosociality toward the synchronous movement partner. This supports the hypothesis that the social effects of interpersonal synchrony are not driven by mood effects (Wiltermuth & Heath, 2009) but rather, that such interactions provide useful social information about synchronously-moving partners.

This question of whether interpersonal synchrony drives specific or generalized helping has been explored in one prior experiment with adults (Reddish, Bulbulia & Fischer, 2013). However, as mentioned in the discussion of Chapter 3, methodological issues with this experiment make it difficult to interpret the authors' results. As such, Chapter 3 provides us with the most explicit test of this question about how affiliative behaviour is directed following interpersonal synchrony.

Chapter 4 explored the idea of directed helpfulness further by investigating how interpersonal synchrony and asynchrony influence infant interactions with an affiliate of the bounce partner. We developed two versions of a live skit to demonstrate to infants that two experimenters were either positively affiliated or not affiliated. Infants were then bounced either in- or out-of-synchrony with one of these experimenters, and then performed the instrumental helping tasks with the other experimenter. We found that when infants interacted with the positive affiliate of their bounce partner, infants in the synchrony condition helped this person more than infants in the asynchrony condition. However, when infants interacted with the non-affiliated independent experimenter, movement condition did not influence helpfulness.

Together with our results from Chapter 2 and 3, the results of Chapter 4 support the idea that synchronous movement encourages infants to help the person they bounce in synchrony with and members of that person's social group, but does not simply put infants into an indiscriminately helpful mood. An additional critical contribution of the study in Chapter 4 is that the experimenter performing the instrumental helping tasks was blind to the movement condition. This strongly suggests that unconscious experimenter signals during the helping tasks did not drive our results in previous experiments.

In Chapter 5, I explored the importance of background music during the interpersonal movement phase, a factor that was held constant in Chapters 2 to 4. Therefore, in Chapter 5, infants listened to non-rhythmic nature sounds instead of music while they were held and bounced either in- or out-of-synchrony with the main experimenter. I found that infants were still more likely to help the synchronously-moving partner more than the asynchronously-moving partner, suggesting that music is not necessary for interpersonal synchrony to influence infant helping. However, I did find interesting differences in fussiness rates, overall rates of helping and speed of helping compared to the results in Chapters 2 to 4, a difference suggesting that infants were generally less content when music was not present. The presence of music in the previous experiments may have had emotion regulating properties that contributed positively to the overall experience. The social effects of interpersonal synchrony have been documented in non-musical contexts before with both adults (e.g. Wiltermuth & Heath, 2009) and more recently, infants (Tuncgenc et al., 2015). However, Chapter 5 is the first investigation to do so using a methodology that has also been used in a musical context, allowing us to make more direct qualitative comparisons.

Collectively, the work presented in this thesis shows that infants help interpersonally synchronous partners over asynchronous partners and that movement predictability does not influence this effect. The early emergence of these effects suggests that interpersonal movement is a salient and important part of social interaction. I have also demonstrated that this increase in infant helping is only directed toward the synchronous partner and members of that person's social group, but does not influence neutral stranger helping. Finally, I found that interpersonal synchrony promotes infant helping even in a non-musical context. By using a paradigm that has been used in a musical context, I was able to highlight that music does provide emotion-regulating effects that are separate from the social effects of interpersonal synchrony. In sum, this work uses novel methodologies to reveal previously untested social effects in 14-month-old infants, and highlights the importance of behaviours that encourage interpersonal synchrony (e.g. musical behaviours) in early development.

Limitations of the Thesis Research and Future Directions

The present thesis is the first to demonstrate that interpersonal synchrony influences infant helpfulness. However, there are limitations to these studies that must be addressed. For example, the methodology did not allow for experimenter blindness during the interpersonal movement conditions, and the sensitivity of the helping measures was limited. These results also raise many interesting questions about interpersonal synchrony and infant social understanding that can be explored in future studies. For example, how might interpersonal synchrony influence other affiliative behaviours such as sharing and comforting? How long do the prosocial effects of interpersonal synchrony last? What cues in the skits from Chapter 4 are actually driving infant third-party social evaluations? Why did the lack of music in Chapter 5 lead to higher levels of infant distress? These ideas are discussed below.

Experimenter blindness is an important concern for paradigms such as these where experimenter behaviour may not be consistent across participants, and could potentially confound results. The experimenter's behaviour during the helping tasks was of particular concern. In Chapter 2 and 3, for example, this person may have unknowingly displayed more need and behaved more positively with infants from the synchronous condition than those from the asynchronous condition. However, in Chapter 4, each infant was bounced with one experimenter and then did the helping tasks with the second experimenter who was completely blind to bouncing condition. Importantly, despite experimenter blindness, the effect of synchrony on infant helping was still found. This indicates that experimenter behaviour during the helping tasks alone could not be driving our effects.

Experimenter bias during the interpersonal movement condition, however, may still be of concern. The experimenter bouncing either in- or out-of-synchrony with the infant cannot be blind to the movement condition. This is problematic because this person may act differently while bouncing with infants synchronously compared to asynchronously, which may be confounded with our manipulation. In pilot tests, I had this experimenter wear blacked-out sunglasses to remain blind, but this resulted in surprisingly low helping rates across all conditions and high rates of infant fussing, suggesting high levels of infant distress and distrust. This result is not especially surprising, considering that even 2-month-old infants look mostly at the eyes when looking at a face (Maurer & Salapatek, 1976), and that 14-month-olds are sensitive to the status (occluded or not) of an adult's eyes (Brooks & Meltzoff, 2002). Therefore, in order to not compromise the social validity of the experiments, experimenters in the interpersonal movement phase could not be blind to movement condition. To account for this lack of experimenter blindness, I had raters who were blind to the conditions and hypotheses rate this person's behaviours from the video recordings, and did not find any evidence of biased experimenter behaviour across conditions (Chapter 2, 3 and 5). The lack of noticeable differences in experimenter behaviour across the movement conditions supports the assumption that experimenter bias during the interpersonal movement condition does not compromise these findings.

Another limitation of this research lies in the sensitivity of the helping measures. The helping tasks used in these experiments, developed by Warneken and Tomasello (2007; 2008), produce large amounts of between-subject variability. While these tasks are sufficiently sensitive for us to measure differences in helping rates following synchronous versus asynchronous interpersonal movement, the large between-subject variability inherent in these measures do not lend well to studying how gradients of asynchrony influence prosociality. A paradigm that can be used to investigate how varying degrees of asynchrony influence prosociality needs to be developed so that these questions can be addressed, first with adults and later with children and infants.

The results of this research program also raise interesting questions about what kinds of prosociality are influenced by interpersonal movement. Here, we find results only in our measures of instrumental helping. In Chapter 3, we did add in a measure of sharing, but found a ceiling effect in sharing rates across the movement conditions. Helping, sharing and comforting follow different developmental trajectories, and require different cognitive and social abilities (Kuhlmeier et al., 2014). Using more discriminating measures, it would be interesting to investigate how interpersonal synchrony influences these various forms of prosociality in infants as well as children and adults.

Another interesting question for future research concerns the latency of this social effect. Prosociality following interpersonal synchrony has always been measured immediately. Whether these effects are only immediate, or if they persist for hours, days, or longer, is yet unexplored. This is an important question since increases in affiliative behaviour that persist over time would suggest that interpersonal synchrony influences one's dispositional impression of their movement partner. Such long lasting dispositional impressions have been recently reported in 7 to 15-month-old infants, who are more likely to select a 'nice' puppet over a 'mean' puppet one week after watching these puppets behave in 'nice' and 'mean' ways, respectively (Tasimi & Wynn, May 2016). Increases in affiliative behaviour that are only immediate, on the other hand, would suggest that these boosts in prosociality are driven by transient boosts in sociability, and have little to do with long-lasting dispositional judgments about one's movement partner.

Given that I found evidence for cued and specific increases in infant helping following interpersonal synchrony (Chapter 2 and 3), and that mood has not been reported to be influenced by interpersonal synchrony in adults (Wiltermuth & Heath, 2009), I would predict that these prosocial effects should persist over time. Such persistent effects on dispositional social judgments support "partner choice" models of prosociality, which suggest that directing prosociality toward "better" social partners increases the likelihood of reciprocity, and is therefore adaptive (Dunfield et al., 2014). Such models that include reciprocity would require that dispositional judgments persist over time. If interpersonal synchrony is a cue for partner suitability, dispositional impressions formed in response to this cue should be long lasting.

The third-party relationship skits used in Chapter 4 raise other interesting questions about infant social judgments. Third-party understanding in infants has been under-researched. These skits may be adapted for use in future experiments. However, we do not yet know what components of these skits cue infants to form expectations about these third-party relationships. Future research should therefore investigate how the social cues present in the skits are interpreted by infants, and whether these skits influence third-party expectations in infants younger than 14-months-old.

Chapter 5 also raises interesting questions about how and why the presence of music improves the overall pleasantness of the infants' experiences. These findings fit well with recent research demonstrating that listening to music can help infants regulate their emotions (Corbeil, Trehub & Peretz, 2015). However, which components of music and music engagement (e.g. familiarity, acoustic properties) drive its effectiveness as an emotion regulator are yet unknown.

One main question that was not directly addressed in this research program is the question of *why* interpersonal synchrony influences social behaviour. Researchers have theorized that these effects may be driven by a preference for self-similarity (Valdesolo, Ouyang, & DesSteno, 2010), increases in person-perception (Macrae, Duffy, Miles & Lawrence, 2008; Woolhouse et al., 2016), and/or neurohormonal factors such as the release of endorphins (Freeman, 2000; Tarr, Launay & Dunbar, 2014). Research with adults should attempt to investigate how these factors contribute to the social effects of interpersonal synchrony. The present research program does, however, highlight that whatever factors drive these social effects influence behaviour early in development.

Broader Applications of the Thesis Research

The results of this thesis suggest that engaging with others in a synchronous way can encourage infant prosocial behaviour. These results also suggest that encouraging musical activities (which elicit high levels of interpersonal synchrony) between caregivers and infants may contribute positively to this important social bond. When a caregiver uses gentle movement to engage synchronously with his or her child, both individuals may interpret this as a positive social experience. Caregiver-infant interactions influence infants' continued social and emotional well-being, with long-term social and emotional implications (e.g., Bakeman & Brown, 1980; Kopp, 1989; Sroufe, 2005). If interpersonal synchrony could be used to positively influence the bidirectional caregiver-infant relationship, this would be especially important for at-risk mothers (e.g., teen mothers; mothers with post-partum depression). Future research should investigate whether incorporating interpersonally synchronous movement to music into existing interventions for at-risk mothers would lead to positive social and emotional outcomes.

Musical behaviors such as singing and dancing are often present in social situations in which the goal is to feel affiliated with others, such as at parties, religious ceremonies, weddings, funerals, and in the military. While music may not be necessary for the effects of interpersonal synchrony to influence social behaviour, music creates a natural context in which synchrony can be easily achieved, due to our propensity to move our bodies to the underlying beat in music (for example, see Patel & Iversen, 2014; Repp, 2006; van der Steen & Keller, 2013; Trainor, 2015). In addition to easily encouraging interpersonal synchrony, music can have emotion-regulating effects (Corbeil, Trehub & Peretz, 2015; Fukui & Yamashita, 2002; Stefano, Zhu, Cadet, Salamon & Mantione, 2004; Trehub, Ghazban & Corbeil, 2015). By combining interpersonal synchrony with emotion regulation, musical behaviours become important social tools for fostering group cohesion. This may explain why humans, who are socially driven, invest so much time and energy into musical endeavors. This thesis has implications on how musical engagement can be an important social tool even for young infants.

These results also support the use of musical activities in children's classrooms. In line with this sentiment, recent research has shown that children with poor prosocial skills show improvements in self-reported sympathy and prosociality levels after a year of ukulele training in the classroom, a group-based lesson that encourages high levels of interpersonal synchrony and joint music making (Schellenberg, Corrigall, Dys & Malti, 2015). Kirschner and Tomasello

(2010) also reported higher levels of helping and cooperation between pairs of 4-year-old children who had played together in a musical compared to a non-musical way, showing that these effects of prosociality influence behaviour between school-aged peers. Recently, a new study with 8-year-old children demonstrated that interpersonal synchrony between groups of children can negate out-group antipathy (Tuncgenc & Cohen, 2016). Together with the results of this thesis, studies like these suggest that musical engagement encouraging interpersonal synchrony can be used in the classroom and daycare to help enhance group cohesion and social inclusion among children. Such findings should be available to policy makers when deciding how to allocate funding to music and dance programs in schools.

Summary

In my thesis, I examined how interpersonal synchrony affects the social behaviour of 14-month-old infants. The results of these studies show that interpersonal synchrony guides infant social behaviour, both in musical and non-musical settings. Furthermore, infants do not only help their synchronous partner more than their asynchronous partner, they also help members of that person's social group. This suggests that infant social behaviour is influenced not only by infants' own interactions with others, but also by their understanding of third-party relationships. My thesis suggests that social interactions through movement and music are an important part of early social development for young infants.

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