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Rhythm and interpersonal synchrony in early social development

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Abstract

Adults who engage in synchronous movement to music later report liking each other better, remember more about each other, trust each other more, and are more likely to cooperate with each other compared to adults who engage in asynchronous movements. Although poor motor coordination limits infants' ability to entrain to a musical beat, they perceive metrical structure in auditory rhythm patterns, their movements are affected by the tempo of music they hear, and if they are bounced by an adult to a rhythm pattern, the manner of this bouncing can affect their auditory interpretation of the meter of that pattern. We review studies showing that by 14 months, infants who are bounced in synchrony with an adult subsequently show more altruistic behavior toward that adult in the form of handing back objects "accidentally" dropped by the adult compared to infants who are bounced asynchronously with the adult. Furthermore, increased helpfulness is directed at the synchronized bounce partner but not at a neutral stranger. Interestingly, however, helpfulness does generalize to a "friend" of the synchronized bounce partner. In sum, synchronous movement between an infant and an adult has a powerful effect on the infant's expression of directed prosocial behavior.

1.0 Introduction

It is intriguing that humans not only have a propensity to move to rhythmic auditory stimuli but that they commonly engage in this activity in groups where social bonding is important and shared goals are desired.[1] For example, music and movement (including dance) are commonly present during religious and ritual ceremonies, important community events such as weddings and funerals, social parties, and during group military exercises, suggesting that engaging in music increases cooperation within groups.[2-6] In the present paper, evidence for a link between synchronous movement and prosocial behavior in adults is reviewed, prerequisites for such behavior are considered, and evidence for the influence of synchrony on helping behaviours in infancy is presented.

2.0 Synchrony and prosocial behavior in adults

Research indicates that synchronous movement between adults increases group cohesion and social cooperation.[7-9] Synchronized movement appears to have prosocial effects whether or not it involves music, but the temporal predictability of musical rhythms provides an ideal context to support synchronized movement. Wiltermuth and Heath (2009),[9] for example, found that adults who walked together in synch or moved a cup in synch while singing were subsequently more likely to cooperate in a weak link game (where the best outcome for all is when everyone contributes at the highest level, but if one person contributes at a low level, those contributing at a high level suffer most) and to contribute more into a public account in a public goods game (where the group benefits from contributions, but individuals benefit from not contributing) compared to people who did similar activities but not in synch. Synchronous movement also increases trust[7,10] and affiliation[11] between those involved. Furthermore, people are more likely to engage in altruistic acts (defined as acts that require personal sacrifice) aimed at people with whom they previously moved in synch compared to out-of-synch.[9,12] Although the mechanisms by which these social effects of synchronous movement operate are not yet entirely understood, people rate synchronously moving partners as more similar to themselves than asynchronously moving partners,[8,12] and show enhanced perception of, and memory for, synchronously moving partners.[8,13,14] Interestingly, one study indicates that synchronized drumming increases activity in the striatum (specifically the caudate), an area associated with reward (both material and social), prosocial behavior, and modulation of future behavior.[15]

3.0 Prerequisite processes and their development

A number of prerequisite processes can be identified that are necessary to establish a causal connection between synchronous movement and prosocial behavior in the context of music. The metrical structure of the music must be extracted from the musical surface. The ability to connect motor movements with the auditory beats of the music must be present. Whether or not other people are also moving in synch must be perceived, for example, from seeing their movements or hearing the results of their movements. Some understanding of people as social agents must be present. And, finally, some appraisal such as of self-similarity must be made, which affects affiliative evaluation, social perception and, ultimately, prosocial or altruistic behavior. Music is particularly interesting with respect to early social development as caregivers across cultures sing to infants[16,17] and this singing is used to communicate emotionally and to help infants regulate their state.[18]

3.1 Development of the perception of metrical structure

Musical rhythms consist of patterns of event onset-to-onsets of different durations. From at least as young as 2 months of age, infants can discriminate changes in tempo[19] and changes in simple rhythmic patterns.[20-22] From musical rhythm patterns, adults readily extract a steady underlying *beat* or pulse, to which they might clap their hands or tap their foot. These beats can be arranged in different perceptual groups or *meters*. For example, every second beat might be accented, resulting in a duple meter (e.g., march) or every third beat might be accented, resulting in a triple meter (e.g., waltz). At some levels of the metrical hierarchy beats will be evenly spaced (isochronous), but at others they might be non-isochronous but regular (e.g., alternative groups of two and three beats). Sensitivity to meter emerges early in development. Perceptually, 7-month-old infants show surprise when a meter is changed from duple to triple or vice versa.[23] There is even evidence that newborns may extract the meter from auditory rhythm patterns, in that they show larger event-related potential (ERP) mismatch negativity (MMN) responses to the omission of a strong beat compared to a weak beat in an ongoing rhythm pattern.[24] The particular meters commonly used vary from musical system to musical system and infants' perception becomes specialized for the meters in the music in their environment by the end of the first year after birth.[25] In sum, infants perceive metrical structure very early on and their perception is shaped by experience during infancy.

3.2 Development of the ability to entrain movement to an auditory beat

Many species execute rhythmic movements, including those used in locomotion (e.g., walking, running, hoping, swimming, flying), feeding (e.g., chewing, pecking), and sound production (e.g., vocal chord vibration, limb or wing rubbing). Many species also synchronize movements across individuals, such as fireflies that pulse together, birds that flap their wings together and fish that move their fins and tails together. However, few species have been shown to synchronize rhythmic movements with an external auditory beat.[26,27] While the vast majority of humans readily, even spontaneously, engage in movement to a predictable beat such as found in music,[26,28-30] convincing evidence of this in other species has been found only for a few vocal learning birds[31,32] and one sea lion who was trained in captivity.[33]

Developmentally, it takes years for human children to become adept at synchronizing movements with an auditory beat. For example, 3-year-olds are poor at clapping in time with a metronome beat,[34] a task that is easy for adults.[28] The tempo range over which young children can produce a steady beat when they clap is restricted to beat onset-to-onset times around 400 ms,[35] whereas adults are able to synchronize across a wide range of tempos.[29,30] Furthermore, the limitations in young children's entrainment abilities do not appear to be restricted to clapping movements; although young children will move to music by hopping, swaying, and circling, etc., and these movements are generally not related to the tempo of the music.[36] By four years of age, children begin to demonstrate robust entrainment.[34,35,37,38] Interestingly, when entrainment is socially supported, children as young as 2.5 years show some evidence of entrainment; at this age, children showed evidence of entrainment when drumming with a human partner but not when drumming with a machine that hit the drum.[39] And although 4.5-year-old children could entrain their drumming in both conditions, they were more accurate when drumming with the human than the machine partner.

Given that even young infants perceive metrical structure in rhythm patterns, it is possible that young children's poor ability to entrain is due in large part to motoric immaturity. Indeed, although infants 5-18 months were found not to entrain to music, they did move more in response to music than to speech, and tended to move faster to music with faster tempi.[40] This suggests that the connections between motor and auditory systems may be present early in development, but the limiting factor is actual motor control of movement.

One way to examine early connections between motor and auditory regions is to actually move infants (rather than expecting them to execute the movements) and determine whether this has an influence on auditory perception. Phillips-Silver and Trainor (2005)[41] did just this. They presented infants with an ambiguous auditory rhythm pattern, that is, one that could be interpreted metrically in more than one way. Specifically, they presented a repeating 6-beat pattern with no physically accented beats that could be perceived either as two 3-beat groups (as in a waltz) or as three 2-beat groups (as in a march). Half the infants were held and bounced on every second beat and half on every third beat. After 2 minutes of this movement experience, using a paradigm in which infants controlled how long they listened to each pattern by their head movements, we found that infants preferred to listen to the rhythm pattern with accents that matched how they had been bounced. That is, infants bounced on every second beat of the non-accented ambiguous pattern preferred to listen to a version of the pattern with accents added on every second beat, whereas infants bounced on every third beat of the non-accented ambiguous pattern preferred to listen to a version of the pattern with accents on every third beat. From this study it can be concluded that strong links exist for rhythm between motor and auditory domains in infancy, as in adulthood.[42,43]

In adults, fMRI studies indicate that simply listening to an auditory rhythm activates motor networks in the brain.[44-47] EEG and MEG studies show that responses from auditory cortex follow the tempo of the music[48,49] and that listening to an auditory rhythm causes oscillatory activity in the beta band (around 20 Hz) in both auditory and motor regions.[50] One study shows similar entrainment of oscillatory beta band responses to the tempo of an auditory rhythm in school-aged children,[51] but the neural underpinnings of entrainment in infants has not yet been investigated. In any case, the existing literature shows that prerequisite entrainment abilities, namely the association between auditory and motor interpretations of meter and rhythm, are present in infancy to support links between movement synchrony and social behaviour.

3.3 Early development of social understanding

Increasing evidence suggests that humans are most different from other species, including those that are genetically most closely related, in terms of social cognition[52] and that by one year of age, social development is well underway.[53] Motor entrainment between individuals is a specialized form of joint action (for a review, see [54]), in which individuals coordinate their actions in order to accomplish joint physical or communicative goals. Before one year of age, parents and infants are already engaging in joint action, and the amount of coordination between mothers and infants at 3 and 9 months of age predicts infant self-regulation and future IQ and empathy.[55] With respect to music, infant head, body, hand, and leg movements are most synchronized to their mother's singing at the beginnings and ends of musical phrases,[56] suggesting the presence of a precursor to entrainment.

Another important ingredient in early social cognition is joint attention, the ability to coordinate attention with a social partner in order to inform and share experiences.[57] As young as 12 months of age, for example, infants (unlike chimpanzees) will initiate joint attention by pointing to objects in order to get others to attend to them.[58,59] At even younger ages, infants show preferences for other people who exhibit certain behaviours such as smiling[60-62] and making direct eye contact.[63] Infants also show preferences for others who are similar to themselves.[64] Furthermore, young infants understand social agents as having intentional goals. Infants 6 to 10 months of age approach objects that have helped another object and avoid those that have hindered another object from achieving a goal.[65] Furthermore, 3-month-olds look longer at an object previously seen to help another object climb a hill compared to an object previously seen to hinder another object from climbing the hill.[66]

Instrumental helping behaviours, an early manifestation of altruism, emerge before 18 months of age.[67,68] Infants as young as 14 months can recognize the goal of another person and spontaneously help them to achieve this goal, without any reward. Specifically, in one study, 14-month-old infants were shown to help adults by giving them out-of-reach objects needed for the adult to achieve a goal; for example, during a task in which the adult was pinning towels on a clothesline, when the adult "accidentally" dropped a clothespin, the infants picked it up and handed it back to the adult more often than when the adult purposely dropped the clothespin.[69] In sum, the basic elements of social cognition and prosocial behaviour are present in infants by 14 months of age. Together with their ability to perceive the meters of auditory rhythms, and the existence of connections between auditory and motor domains for rhythm, as reviewed above, it is reasonable to ask whether synchronous movement between a 14-month-old infant and an adult would lead to increases in prosocial behaviour in the infant as it does in adults.

4.0 Interpersonal synchrony and prosocial behavior in infancy

In a series of studies we have tested whether the experience of interpersonal synchrony in a musical context leads to increased altruistic behaviours in 14-month-infants.[70,71] The basic design included an *interpersonal movement phase* followed by a *prosocial test phase*. During the interpersonal movement phase, an assistant stood and held the infant in a forward-facing carrier such that the infant faced an experimenter. The infant listened to Twist and Shout by The Beatles over speakers for 145 seconds. The assistant and experimenter listened to separate beat tracks over headphones, which instructed them on how to bounce. The synchrony of bouncing between the experimenter and infant was the manipulation of interest. During *synchronous bouncing conditions*, the beat tracks of the assistant and experimenter matched and they bounced to the tempo of the music. In the original study, during *asynchronous bouncing conditions*, the experimenter bounced either 33% slower or faster than the infant. Additionally, during *antiphase bouncing conditions*, the infant and experimenter bounced at the same tempo, but the highest and lowest points of their movement trajectories occurred at opposite times. Both the assistant and the experimenter wore Nintendo Wii remotes to measure their movement trajectories, and the experimenter was video taped in order to ensure that her behaviour was consistent across conditions.

During the *prosocial test phase*, infants completed instrumental helping tasks based on those of Warneken and Tomasello (2007)[69]. For example, during the paper ball task, the experimenter picks up paper balls with tongs and places them in a bucket, and tries to get paper balls that are out of reach. During the marker task, the experimenter draws a picture and "accidentally" drops a marker off the table and out of reach. During the clothespin task, the experimenter "accidentally" drops a clothespin out of reach while attempting to clip up dishcloths on a clothesline. For each task, the trial begins when the object is dropped and/or signaled to be out of reach. For the first 10 seconds the experimenter gazes at the object. For the next 10 seconds, she alternates looking at the infant and the object. And for the last 10 seconds, she adds vocalization (e.g., "my marker!"). Trials ended when the infant picked up and returned the object or after 30 seconds. The experimenter was video taped in order to ensure that her behaviour was consistent across conditions.

The initial study found that infants helped the experimenter significantly more if they had bounced to music in synchrony with her compared to if they had bounced out-of-sync.[70] Analyses of the movement trajectory data during bouncing revealed no systematic differences in individual bouncing across conditions, and adults who rated video clips of the experimenter during both phases of the experiment were unable to detect any differences across conditions, including in bouncing quality, happiness displayed by the experimenter, and experimenter interaction during the helping tasks. These analyses indicate that the experiment was well controlled. Thus, remarkably, less than three minutes of synchronous movement experience can increase infants' prosocial behaviour. Interestingly, the increase in helping occurred primarily during the first 10 s, suggesting that it was spontaneous in nature. Delayed helping, defined as occurring after the first 10 s and potentially reflecting compliance, was significantly related to personality variables as measured by the Infant Behaviour Questionnaire (IBQ), including dispositional positivity and willingness to approach novel objects,[72] whereas spontaneous helping during the first 10 s was not.

A follow up experiment showed that antiphase bouncing also subsequently increased spontaneous helping in 14-month-old infants when compared to asynchronous bouncing.[70] This indicates that identical movements are not necessary for this social effect, but that the tempo of the oscillatory movement may be critical. This is consistent with a study of dancing in adults, which found that dancers who made synchronously timed, but not necessarily identical, movements were subsequently able to remember more information about each other compared to dancers who moved at different tempos.[14] It is also possible that antiphase movement, in particular, is privileged, and there is a rich literature on its stability in adults.[29,30] Future studies could disentangle effects of phase and movement similarity.

One important question is whether infants' experience of synchronous movement is pleasurable and causes them to be generally more helpful (i.e., acts as a social prime), or whether the effect is targeted at the person with whom they experienced the synchrony (i.e., acts as a social cue). We reran the initial experiment described above, but this time a non-bouncing neutral stranger was present in the room during the interpersonal movement phase.[71] As in the initial experiment, infants bounced either in sync or out-of-sync with the experimenter. During the prosocial test phase, we measured infants' willingness to help both the experimenter and the neutral stranger. With the experimenter, we replicated the effect of synchronous movement experience: infants who bounced in synchrony with the experimenter were subsequently more likely to help the experimenter compared to infants who bounced out-of-sync. However, there was no effect of bouncing condition on helpfulness toward the neutral stranger. Thus, prosocial consequences of synchronous movement experience are targeted at the person with whom the movement was experienced.

Music making often involves groups of people and, indeed, it has been suggested that music making increases within-group cohesion.[73] The specificity of prosocial consequences of synchronous movement can be investigated further by examining whether infants display increased helpfulness towards friends (positive affiliates) of a synchronous bouncing partner but not towards neutral affiliates. In a recent study, we had infants initially watch the experimenter interacting with a second experimenter.[74] In the *positive experimenter affiliation* condition, the two experimenters engaged in similar gestures and solved a problem together. In the *neutral experimenter affiliation condition*, the two experimenters engaged in similar actions, but did not interact. The results revealed that if the infant bounced synchronously with one of these experimenters, they showed increased helping toward the second experimenter if they were in the *positive experimenter affiliation* condition, but not if they were in the *neutral experimenter affiliation* condition, and there were no effects if they bounced asynchronously with the experimenter. Thus, the prosocial effect of synchronous movement extends to third parties who are in the same social group.

5.0 Conclusions and future directions

The studies presented here indicate that synchronous movement to music has immediate and powerful prosocial effects, increasing altruistic behaviours in infants as young as 14 months. Furthermore, these altruistic effects are targeted at synchronously moving partners and their positive affiliates. Infants younger than 14 months do not readily engage in helping behaviours. However, they still form expectations about social behaviours, preferring, for example, those who are attractive,[75] use infant-directed speech,[76] and engage in prosocial behaviour.[65,77,78] Thus we are currently exploring the possibility that during the first year after birth, infants expect synchronously-moving partners to engage in prosocial behaviours to a greater extent than asynchronously-moving partners.

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