Playing with the beat

Chapter 1

Playing with the beat: a process-oriented approach to studying sensorimotor synchronization in early childhood*

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Abstract

This chapter focuses on sensorimotor synchronization (SMS) in early childhood. After a brief review of recent embodied accounts of music cognition, we outline two approaches in SMS research: the more common outcome-oriented approach that measures accuracy of children's behaviour and the process-oriented approach which explores the type and variety of spontaneous rhythmic responses. Building on a body-as-constraint perspective, we argue that the latter approach can provide insights into how a developing child freely chooses to dynamically interact with the beat and thus self-regulate their unique perceptual experience. A new, process-oriented method called *Ana's Game* is then described, with illustrative examples.

Introduction

Infants and young children, like adults, often move spontaneously and rhythmically in response to music. It has been shown that such movements tend to become faster when the musical tempo is faster and are often accompanied by smiling when the movement and musical tempo are close (Zentner & Eerola, 2010), suggesting a recognition of and pleasure in the synchronization process. Recent research has suggested that this rhythmic ability is present at birth (see Provasi, Anderson, & Barbu-Roth, 2014), and there are even indications that fetuses of 35-weeks gestation show movement when exposed to music (Kisilevsky, Hains, Jacquet, Granier-Deferre, & Lecanuet, 2004).

Research into the ability of young children to synchronize with a steady beat often focuses on a specific motor task, such as manual tapping (e.g. Provasi & Bobin-Bègue, 2003). While this kind of prescribed motor response is ideal for controlled experimental design purposes, it relies on fine motor skills that are not always fully developed in each child (Gallahue, Ozmun, & Goodway, 2012). Additionally, direct movement instructions restrict a child's sensorimotor repertoire, potentially excluding employment of their more natural, spontaneous beat-finding process. Here we suggest that a complementary and more embodied approach to studying sensorimotor synchronization (SMS) in early childhood is to employ playful activities, during which young children are invited to make their own free choices of movement.

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The chapter begins by presenting an embodied and enactive account of music perception, including the body-as-constraint thesis (Foglia & Wilson, 2013). We then focus on SMS in early years by outlining what we describe as outcome- and process-oriented research approaches, and the latter is discussed in some detail. Finally, two examples of children moving freely to rhythmic stimuli are given, in order to illustrate a new, process-oriented approach to SMS called *Ana's Game*.

Embodied Music Cognition: Perception in Action

Several current theories of human cognition indicate that in order to fully understand music perception, we must take into account the role of the body. For example, from the perspective of *Embodied Music Cognition* (Leman, 2008) the body is not peripheral to meaning-making in musical experience, but rather constitutes a natural mediator between the sonic environment and the agent's mind. Much empirical work in this area focuses on the study of body movement responses that can be seen to reflect the structural and expressive qualities of a musical stimulus (e.g. Amelynck, Maes, Martens, & Leman, 2014; Burger, Thompson, Luck, & Toiviainen, 2013; Maes, Leman, Palmer, & Wanderley, 2014). Another approach is to study the ways in which body movements can affect music perception, such as by helping to disambiguate specific musical features (e.g. Maes & Leman, 2013; Phillips-Silver & Trainor, 2005). It could be argued that the former type of sensorimotor research represents a classical ecological view, in which the listener responds physically to a musical environment, while the second type takes a more deeply *enactive* view, investigating how the bodily responses of a listener affect the perceptual content itself (Maes et al., 2014).

Enactivism (Varela, Thompson, & Rosch, 1991) proposes that individuals are autonomous agents able to construct their cognitive experience through dynamic interactions within a given situation. Individuals build meaning from the way in which they interact physically with their environment: "perceiving is [then] a way of acting" and thus it is "determined by what we do (what we know how to do)" (Noë, 2006, p. 1). Cognition will depend on an individual's sensorimotor capacities and history of interactions within a particular context. Musical perceptual experiences thus become dynamic interactions between the sensorimotor capabilities of the listener and the sonic environment. Listeners explore, manipulate and interact *with the world* using their own bodily skills, which means they are actively engaged in the generation of musical meaning.

This idea of enacting our own music perception is intrinsically linked with the concept of *musical affordances*. Such affordances arise from a musical stimulus and represent a dynamic interaction between the structural features of the music (such as a salient beat) and the bodily characteristics and sensorimotor response capabilities of the listener. Musical affordances are thus defined relationally: "a perceiver, by virtue

of being embodied in a particular sort of way – and possessing an accumulated history of environmental interactions – will experience affordances as furnishing different sets of interactive possibilities" (Krueger, 2014, p. 2).

This central role of the body in recent accounts of music perception leads us to the body-as-constraint thesis (Foglia & Wilson, 2013), which suggests that there is a strong link between the properties of a person's body and the (musical) concepts s/he can acquire. The idea that cognitive processes are functionally dependent on the body and on unique interactive possibilities that their particular body affords, means that different individuals' understandings may diverge when perceiving the same music, due to the distinct affordances they recognize. A body-as-constraint proposition thus becomes particularly relevant when studying young children who are undergoing significant developmental changes. The dependence of perceptual processes on a particular body's characteristics and repertoire of motor skills means that young children may create a distinct conceptual world from older children and adults, given their developmental differences. What they perceive and understand is based not only on what they do but also on what they are capable of doing.

Finally then, we turn to *Dynamic Systems Theory* (DST) - a framework proposed by Thelen & Smith (1994) to understand cognitive development in infancy and early childhood. DST highlights the uniqueness of individual children's developmental pathways and the fundamental role of experience in meaning-making processes. Motor patterns will emerge at an individual level, given that each child, with their own biological heritage and history of interaction, self-regulates their own learning in response to the opportunities and constraints of a particular challenge. A child does this by spontaneously exploring a range of possible movement solutions that will ultimately lead him/her to an optimal and more efficient behavior.

This range of converging theory and evidence on the importance of the role of the body in music perception - that is, the idea that such perception emerges from a dynamic and exploratory interaction between each physically developing child and their own understanding and experience of a musical stimulus - is important to consider when investigating the SMS behavior of young children.

Sensorimotor Synchronization (SMS) in Young Children

Motor responses to a steady beat are often considered a spontaneous and automatic process (Schaefer & Overy, 2015). *Being moved* by a regular pulse in a seemingly effortless way involves, according to Leman (2008), a distinct experience from having a clear intention to *move to* and synchronize with the beat. The first type of experience reflects the direct impact of the physical energy of sound on the human motor system. As follows, the beat is recognized as "the most natural feature for synchronized movement because it appeals to fundamental biomechanical

resonances" (Leman, 2008, p. 112). This resonance effect is also understood as a consequence of "predictions of local bursts of energy in the musical audio stream, in particular to the beat and rhythm patterns" (p. 96).

Sensorimotor synchronization (SMS) is defined as the temporal coordination of a rhythmic action with a predictable external rhythm, and has been extensively researched in adults (for a recent review see Repp & Yi-Huang, 2013). As mentioned above, this phenomenon has also been studied to some extent in very young children (Provasi & Bobin-Bègue, 2003), even as young as five months old (Zentner & Eerola, 2010). However, children have not, to date, been studied as extensively as adults, at least in part "due to the difficulty young children and infants have performing rhythmic actions when asked to do so in an experimental setting and the immature motor system's ability to produce periodic patterns" (Provasi, Anderson, & Barbu-Roth, 2014, p. 2).

Broadly speaking, the SMS research conducted with children to date can be described as either outcome-oriented or process-oriented. Outcome-oriented approaches to SMS focus on measuring the accuracy of children's ability to synchronize to an external rhythm, that is, they assess how well motor actions are temporally coordinated with a steady beat. This approach is widely used in SMS research in early years (e.g. Kirschner & Tomasello, 2009; Provasi & Bobin-Bègue, 2003) and is characterized by the use of a task in which children are instructed to synchronize their movements in time to a beat with a closed instruction that encourages goal directed action (e.g. *'tap-to-the-beat'*).

Studies using this approach have found that children's SMS ability gradually improves with age, particularly if the rhythmic stimulus is close to their individual spontaneous motor tempo (SMT) (Drake, Jones, & Baruch, 2000; Jones, Boltz, & Klein, 1993; McAuley, Holub, Jones, & Johnston, 2006; Provasi & Bobin-Bègue, 2003). In children aged 2 ½ to 5-years-old, the average value of SMT is around 400-500 ms (Drake et al., 2000; McAuley et al., 2006), compared with around 600 ms in adults (Fraisse, 1982). Moreover, young children show a limited synchronisation range, which gets wider and more adaptable with age, particularly in slower tempi (Van Noorden & De Bruyn, 2009).

The SMS task in outcome-oriented approaches is usually constrained to a specific predetermined action that remains fixed throughout the experiment. Tapping (finger, hand or stick) is often the conventional action chosen by researchers (Drake et al., 2000; Kirschner & Tomasello, 2009; Provasi & Bobin-Bègue, 2003). This particular gestural pattern, which involves the repetitive motion and engagement of small muscles, has been used to measure the SMS accuracy of children as young as 1 ½ of years of age (Bobin-Bègue & Provasi, 2008). However, given that in very young children gross motor skills are more developed than fine motor control (Gallahue,

Ozmun & Goodway, 2012), it could be argued that the choice of tapping, while experimentally convenient, might be developmentally less appropriate in assessing young participants' synchronization abilities than the use of free whole-body movements.

By prescribing how children should move in response to a beat, much outcome-oriented research limits the possibility of a more embodied interaction with the beat, on children's own terms and through the choice of their own actions. One might even claim that the approach adopts a disembodied view of perception, given that the dynamic interplay between the structural features of the music stimulus and children's body properties and sensorimotor capabilities is not fully accessible. Instead, in most outcome-oriented designs, the body tends to assume what might be considered a passive role as a merely mechanical executor. Moreover, such data collection methods "are often motorically too demanding, require too much concentration, or are otherwise unattractive to young children" (Eerola, Luck, & Toiviainen, 2006, p. 473).

Thus, several researchers have considered an alternative approach to studying SMS in early years. Rather than paying attention to the end result of children's performance, what we describe here as a process-oriented approach focuses on the type and variety of responses exhibited while completing a SMS task. In other words, it places priority on children's own sensorimotor repertoire and on how these movements are explored and executed *throughout* the challenge. This approach is usually based on an embodied and enactive framework which in practice invites children to explore and self-regulate their own movement behavior. Specifically, an 'undisclosed' beat-finding task is given, such that young participants are not specifically instructed to follow the beat, but are invited to *move-as-they-wish* in a given space, to a musical stimulus (Eerola et al., 2006; Moog, 1976; Sims, 1985).

A *move-as-you-wish* paradigm gives children the opportunity to make their own free and individual choices of movements when responding to music. Rather than using predetermined actions such as finger tapping, their sensorimotor repertoire is spontaneously selected in accordance with each child's body specificities and sensorimotor capabilities. The few studies using this process-oriented approach to studying SMS in early childhood have generally reported that pre-school children (e.g. aged 3-5) exhibit a wide range of rhythmic movements (e.g. bouncing), and do not generally move in time with the musical beat (Moog, 1976; Eerola et al., 2006; Sims, 1985). Children tend to vary their type of movement according to the musical tempo and to the beat salience of the musical stimuli (Sims, 1985), while the variety of movements has been reported to decrease with age (Moog, 1976). Eerola et al. (2006) have identified and classified young children's movement choices into three general categories of *hoppers*, *swayers* and *circlers*.

While these findings provide an excellent starting point from which to further investigate children's repertoire of spontaneous rhythmic responses, there are still several important methodological challenges to overcome when using a process-oriented approach. For example, unfamiliarity with the research setting and team can result in children feeling uneasy or unwilling to move freely, sometimes withdrawing from participation (Eerola et al., 2006) (a problem also prevalent in outcome-oriented SMS research with young children) or in researchers inviting children to use prescribed movements (Moog, 1976). Other difficulties have included parents being present and encouraging children to move with verbal persuasion, or familiarity with the music leading to children using previously learned dance movements (see Eerola et al., 2006). Finally, the observational methods used to date and the interest in common features of children's rhythmic behaviour have led to the use of rather broad categories of movement-type, rather than focusing on individual differences and the uniqueness of each child's choices of movement.

The methodological challenges aforementioned, in particular children's unwillingness to move freely to music while being observed within a research setting, highlight the need to explore effective ways of engaging children in SMS tasks. With the purpose of overcoming these limitations a new process-oriented approach was developed; '*Ana's Game'* (Almeida, 2015).

Developing *Ana's Game*, a process-oriented approach to SMS

Playing with the beat

The absence of an explicitly playful element in previous *move-as-you-wish* SMS studies may have affected some young children's reluctance to move, or to make free choices of movements. A process-oriented approach entails a great degree of self-regulation, in which young children can be invited to freely explore the interaction possibilities afforded by the music. Given that young children's level of intrinsic motivation and engagement will affect the quality of their movements, and indeed their willingness to make spontaneous movement choices, it is thus fundamental to ensure the creation of a trustworthy and playful research environment for any SMS study. Ideally, for the success of a process-oriented approach, children must experience a state of *flow* (Csikszentmihalyi, 1990), in other words, they should be fully involved while moving to the music and feel that the experience is pleasurable and rewarding. By moving as they wish, children will increase their chances of finding the most effective solution for them to experience the musical beat in a meaningful and enjoyable way.

In a recent observational study involving preschool children (Almeida, Miell, & Overy, in prep), *Ana's Game* was designed to take place within the familiar nursery setting of the children recruited. After trust had been developed between the observer and the young children over a period of three months, the game was then individually

introduced to each child, in a familiar room within the school. The instructions invited children to position themselves within a large square delineated on the floor, to *move* freely to the music and *freeze* with any silence, over a total period of 1 minute 58 seconds. The children responded extremely positively, with a range of energetic movements, smiling and laughter.

Musical Stimulus

In order to elicit spontaneous, free rhythmic responses in young children, it was fundamental to choose the musical stimulus carefully. Firstly, the music needed to elicit spontaneous movements and secondly, it had to support the participants' willingness to move freely and explore their sensorimotor repertoire. The concept of *groove* has in recent years been defined in psychology as the quality of music that affects people's urge to move (Janata, Tomic, & Habermam, 2012). In this way, groove is more related to what one *does* in response to the music than to what one (mentally) *knows* about the music. This particular style of music thus offers the possibility of avoiding giving explicit instruction to move, while still engaging individuals easily in a dynamic embodied interaction with the music.

Highly rhythmic music is identified as an important feature of groove, especially if the beat is clear and salient (Madison, Gouyon, Ullén, & Hörnström, 2011) and with an optimum degree of syncopation (Witek, Clarke, Wallentin, Kringelbach & Vuust, 2014). A short clip (15 seconds) of highly rhythmic, groove-based music was thus used for *Ana's Game* and repeated at four different tempi, separated by brief moments of silence. The first and the last clips were always played at a moderate tempo (100 bpm), with the order of the remaining tempi presented randomly (fast, slow and very slow – 132bpm, 60 bpm and 35 bpm) (Almeida et al., in prep).

Movement Analysis

Body movement responses made by the children during *Ana's Game* were identified and described using Laban Movement Analysis (LMA) (Laban & Ullmann, 2011). LMA is a multi-layered system that provides a framework to observe, analyze and notate the complexity of human movement, and which is increasingly used to study music-induced body movements and explore the correlation between perception and action (e.g. Maes, Van Dyck, Lesaffre, Leman, & Kroonenberg, 2014). In the naturalistic research context of *Ana's Game* it offers the possibility to break down whole *body actions* (e.g. star jump) into different components (e.g. simultaneous body phrasing; vertical plane), enabling a richer description/understanding of the children's spontaneous choices and adjustments while interacting with the music. Of particular interest for this research were the LMA features of *Body* (human body structure and its physical features during the moving process: gestural versus postural, patterns of body connectivity and body phrasing) and *Space* (location in space, direction of travel and peripersonal space: height level, direction and reach of movements).

Examples

Here we present illustrative examples of the free movement choices of two young children engaged in *Ana's Game* (Figure 1). The aim was to describe the unique styles of embodied interaction that each child exhibited, in particular, their sensorimotor repertoire and the strategies used to adjust to a musical changing environment (tempo).

Figure 1. Spontaneous body movements of two young children playing *Ana's Game*. A 5-year-old boy and a 4-year-old girl interact freely with the rhythmic, groove-based musical stimuli.

Example 1

The first example is of a 5-year-old boy who exhibited a whole-body movement pattern which involved stepping to the right with the right foot leading and then crossing the left leg behind the right one, with the sequence then repeated on the left side and alternated continuously throughout each of the four different musical tempi. The style of the sequence suggested that the embodied beat was experienced mainly in the lower-spine and lower-limbs. The movement also involved simultaneous body phrasing, that is, the initiation of multiple body parts at the same time. The child tended to stay in place and explore the combined directions of up-down (vertical dimension) and side-side (horizontal dimension) within his own personal space. His actions were overall maintained at a high height level and at a mid-reach space (i.e. at about an elbow distance away from the body midline).

Although the child maintained the same movement pattern throughout the game, he accommodated changes in the tempo each time a new section started, by varying the tempo of his movements and adjusting the size of his steps. In this way, he showed a physical awareness of musical tempo although without ever directly synchronizing to the beat. The child also introduced subtle variations to his pattern, for instance, when the tempo was slow his torso exhibited successive body phrasing (movements developing successively through adjacent body parts, as a domino effect), whereas when the tempo was fast his hands became engaged in accentuating the beat at almost twice the speed of his feet.

In summary, this child maintained his chosen, whole-body movement pattern throughout the game, but at different tempi he introduced spatial and bodily variations in ways that appeared to effectively support him throughout the repetition of his pattern.

Example 2

The second example is of a 4-year-old girl, whose movement choices varied considerably for each tempo, throughout the game. The movement patterns explored were all whole-body and included stepping-stomping, vertical jumping, split jumping, twisting and turning. Despite the continuous change from one pattern to another the regularity of the movements were never compromised and were approximately synchronized with the moderate and fast tempi, but not to the slow tempi.

The style of the child's movements suggested that the beat was mostly 'located' in the lower-body and, like the boy in the first example, involved simultaneous body phrasing. Her movement patterns occurred mostly in place and thus excluded much traveling in space. An exploration of a variety of repertoire was exhibited and many spatial directions were used, either independently (e.g. up-down) or combined (e.g. up-down & forward-backward). Movements were mostly at a high height level and within a mid-reach space.

Changes in the musical tempo were promptly accommodated through an appropriate increase or decrease of the girl's movement speed. That is, when each new tempo was introduced, the girl tended to continue for a few seconds in her current movement pattern, and then change to a new one. One interpretation of this behaviour is that the old movement pattern was no longer felt to fit the demands of the new tempo and so a more appropriate solution was found. After some initial exploration for a few more seconds, and once an 'optimal' pattern had emerged, the child then would keep this pattern for the rest of the section.

Summary

An important, revealing feature of both children's movements was their spontaneous use of whole-body, bi-phasic, periodic movements in response to the music, albeit executed in different ways. The lack of instruction on how to move led to different movement experiences for each child, from the repetitive stepping movements of the 5-year old boy, to the more varied movement choices of the 4-year old girl, and with varying levels of synchronization with the musical beat. However, both children revealed tempo flexibility, and interestingly, explored different kinds of body and spatial organizations across different tempi.

The two examples illustrate how a process-oriented approach can explore a more enactive view of young children's SMS. The spontaneous rhythmic movements exhibited by both preschoolers seemed not only to reflect some of the structural features of the musical stimulus but also a movement repertoire unique to each child. It is likely that their distinct solutions to the musical challenge (steady beat and tempo changes) were, at least in part, dependent on their body specificities and motor abilities, as well as their history of interactions with music. Moreover, the opportunity to make spontaneous choices of movements and adjustments could potentially invite children to disambiguate the perceptual features of the music. Future research could focus on these aspects of the SMS behavior.

The two examples given also illustrate the willingness of these preschool children to engage with the musical task presented. Both children happily moved continuously while the musical stimuli were being played and '*froze'* during the periods of silence, thus exhibiting full comprehension and indeed enjoyment of the game. In the full study with 50 children (Almeida et al, in prep), only three children declined to play at all while four children made such small movements that their data was difficult to observe, leading to a total of just seven children being excluded from analysis. This is in stark contrast to other SMS studies with young children, in which non-participation/exclusion percentages are often extremely high (e.g. 39%, Eerola et al., 2006), if indeed they are reported.

Ana's Game can thus serve as a successful methodological development of a process-oriented approach to SMS, with possible implications for outcome-oriented research too. The familiarity with the setting and researcher, the playful, game-based format and short time away from the nursery (just 5 minutes), the simple, open-ended instruction (*move as you wish*) and the high groove musical stimulus all encouraged enjoyable participation and spontaneous free movement choices, successfully exhibiting the SMS choices and abilities of the young children.

Conclusions

In conclusion, the concept of Embodied Music Cognition (Leman, 2008) is changing our understanding of music perception by redefining the role of the body in human interactions with music. The body-as-constraint thesis (Foglia & Wilson, 2013) suggests that variability in body characteristics and motor capabilities will affect variability in cognitive processing. Dynamic Systems Theory (Thelen & Smith, 1994) reinforces this view by suggesting that the gradual acquisition of sensorimotor expertise and repertoire is based on a child's unique exploratory experiences and self-regulated interaction with the environment.

Ana's Game can provide a new methodological approach for those who intend to conduct SMS research with young children from a more embodied and enactive perspective. It provides a series of procedures aiming to build trust and familiarity between children and the research team, to encourage the young participants to move freely to music and to make their own choices of movements, and to engage them in a playful and engaging experience. The process may be especially useful when studying SMS in infancy, given that any verbal instructions to participants are completely redundant and researchers have to rely on infants' self-initiated movements and, thus, on their ability to discover how to *move to music* and *follow the beat* (Zentner & Eerola, 2010). Lastly, by specifically focusing on the *process* (the type, richness, variety and complexity of the rhythmic responses) rather than on the *outcome* (accuracy of the behaviour) this approach to SMS may reveal different ways of understanding the role of body movement in music perception in early childhood, with potential future implications for pedagogy and pedagogical interventions.

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