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Review Paper

A developmental and clinical perspective of rhythmic interpersonal coordination: From mimicry toward the interconnection of minds

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ABSTRACT

Imitation plays a critical role in the development of intersubjectivity and serves as a prerequisite for understanding the emotions and intentions of others. In our review, we consider spontaneous motor imitation between children and their peers as a developmental process involving repetition and perspective-taking as well as flexibility and reciprocity. During childhood, this playful dynamic challenges developing visuospatial abilities and requires temporal coordination between partners. As such, we address synchrony as form of communication and social signal per se, that leads, from an experience of similarity, to the interconnection of minds. In this way, we argue that, from a developmental perspective, rhythmic interpersonal coordination through childhood imitative interactions serves as a precursor to higher-level social and cognitive abilities, such as theory of mind (TOM) and empathy. Finally, to clinically illustrate our idea, we focus on developmental coordination disorder (DCD), a condition characterized not only by learning difficulties, but also childhood deficits in motor imitation. We address the challenges faced by these children on an emotional and socio-interactional level through the perspective of their impairments in intra- and interpersonal synchrony.

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1. Introduction

From a developmental perspective, the body, with its sensorimotor abilities, is the fundamental medium through which we

interact with our environment. In this paper, we focus on motor imitation, a bodily interaction critical to the development of human intersubjectivity, particularly with respect to communication and precursory intentionality (Meltzoff and Gopnik, 1993; Nadel and Potier, 2002; Meltzoff and Decety, 2003; Rogers et al., 2005).

Imitation provides the sense of a shared experience and, according to its aspects of “social mirroring, social modeling and self-practice” in infancy, is a prerequisite of the self (Meltzoff, 1990).

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It is also a prerequisite for understanding the complex emotions, intentions, and motives of others (Gallagher, 2001; Meltzoff and Decety, 2003; Trevarthen and Aitken, 2001).

In this review, we explore, through a developmental lens, spontaneous motor imitation between children and their peers. Such interactions reveal a playful dynamic, involving repetition and perspective taking (spatial viewpoint changes), driven by continuous adaptation of behaviors, turn-taking, and position reversals (i.e. in turn imitate and being imitated, Xavier et al., 2013). These exchanges challenge the visual-spatial abilities of children and require temporal precision with flexibility and adaptation in the coordination between partners.

In this way, this dynamic process is characterized by continuous partner reciprocity involving synchrony rooted in rhythmic interpersonal coordination (Delaherche et al., 2012).

Synchrony will be presented as a form of communication and social signal per se and as a facilitator of interpersonal affinity, with an exploration of its potential to give rise to the interconnection of minds (Leclère et al., 2014). We argue that the rhythmic interpersonal coordination involved in imitative exchanges serves as a precursor to the development of empathy, the ability to share the affective states of others, predict others' actions, and stimulate prosocial behavior. Finally, we apply our idea to developmental coordination disorder (DCD), a neurodevelopmental condition characterized by childhood deficits in rhythmic interpersonal coordination and imitative abilities. We address the difficulties experienced by these children on an emotional and socio-interactional level through the perspective of their impairments in intra- and interpersonal synchrony.

2. Peer imitation in children: A rhythmic interpersonal coordination

During child development, early social interaction arises from mimicry and is present at birth (Meltzoff and Moore, 1977). In this instinctive process, an individual copies, or "mimics," the behaviors of another (e.g., facial expressions, vocalizations, movements, postures, gestures). Mimicry relies on the perception-action coupling mechanism whose neural substrate corresponds to the "mirror neuron system" (Blakemore and Frith, 2003; Iacoboni and Dapretto, 2006; Niedenthal, 2007). These neurons fire both when an action is expressed and perceived by another (Gallese et al., 1996; Rizzolatti et al., 1996). Mimicry constitutes a source of primary interpersonal engagement, a concept often referred to as "intersubjectivity" (Gallagher and Meltzoff, 1996; Gallagher, 2004), which serves important social purposes such as communication, bonding, and affiliation (Lakin and Chartrand, 2003). Intersubjectivity is also considered to be a powerful contributor to interpersonal emotional transmission (Carpenter and Nielsen, 2008).

Meltzoff (2005) explains that imitation provides evidence that observation and execution of human actions are innately coupled, with the existence of a structural congruence between the perception of others and personal behavior. Similarly, Gergely et al. (2002) contend that intentionality and the cognizance of one's own emotional states are the consequence of a continuous intersubjective "play of mirrors" between children and their parents that persists throughout development.

This imitative parental relationship also extends to the relationships between children and their peers. Between the ages of 12 and 18 months, children typically develop critical joint attention abilities that establish a perceptual common ground for imitative interaction with others (Moore and D'Entremot, 2001; Tomasello, 2000). Imitation is, from mimicry, a dynamic process, involving accurate and precise timing essential for reciprocal interactions which can take the form of cooperative games in which a child

spatially and temporally coordinates his or her actions with a partner. Nadel-Brulfert and Baudonnière (1982) and Nadel (2011) highlight synchronous imitation between peers, initiated by mimicry during the pre-linguistic period, as a significant hallmark in the development of a child's communication skills. Further, Wallon (1956) writes on the subject of imitative play during early development, noting the profound sociability of childhood, a time during which emotion and its sharing appear as the first means of interpersonal communication. He argues that these interactive exchanges allow partners to individually overcome a state of specular confusion "in which the identity of the ego vacillates with that of the alter ego."

This apparent lack of self-other distinction thus leads to relative uncertainty regarding the personal location of the experience. It is interesting to note the link between this stage of child development and autoscopic phenomena, heautoscopy (i.e., the encounter with an alter ego) in particular, described in pathological conditions such as hallucinations (Brugger, 2002). Further, imitative movements can gradually lead to role reversal and reciprocity, whereby each partner is able to identify his or her own purpose and intentions.

These reciprocal imitative interactions reveal a playful dynamic, involving repetition and perspective taking, driven by continuous position reversals which challenge the visuospatial abilities of its partners (Xavier et al., 2013). They require temporal adaptation with unintentional interpersonal motor synchronization (Fogel, 1993; Ikegami and Iizuka, 2007; Wilson, 2005) rooted in rhythmic coordination between individuals. This mutual adjustment also requires flexibility and fluidity, with alternating periods of continuity-discontinuity and engagement-disengagement.

3. Interactional synchrony: From the experience of similarity to the connection of minds

Interpersonal coordination is typically defined as "the degree to which the behaviors in an interaction are nonrandom, patterned, or synchronized in both timing and form [simultaneous movements or change of postures]" (e.g., Hove and Risen, 2009; Lakens, 2010). Interpersonal coordination is often divided in two fundamental components: behavior matching (i.e., similarity) and interactional synchrony (Bernieri and Rosenthal, 1991). Behavior matching is largely related to imitation, while interactional synchrony refers, more specifically, to the adaptation of an individual to the rhythms and movements of an interaction partner (Condon and Ogston, 1967) and the degree of congruence between the behavioral cycles of engagement and disengagement of the two people (Condon and Ogston, 1967; Leclère et al., 2014).

Synchronization has been found to be a stable pattern in human behavior (Richardson et al., 2005, 2007; Schmidt et al., 1990; van Ulzen et al., 2008) and an important precursor to prosocial behavior (Leclère et al., 2014). It has been shown to foster cooperation (Valdesolo et al., 2010), enhance perceptual sensitivity toward others, and lead to a more positive perception of the interaction partner (Miles et al., 2010; Valdesolo et al., 2010; Kokal et al., 2011).

In addition, synchrony plays a major role in the development of affective regulation, social understanding, and empathy (Feldman, 2007a; Semin, 2007). From birth, children are motivated to synchronously, and intersubjectively, engage in rhythmic actions with others (Trevarthen, 1998, 2004, 2011, 2012). Interactional synchrony is critical to infant-mother relationships and, as an early-learned life experience, has been associated with improved communication and prosocial behavior in typically developing children (Siller and Sigman, 2002; Saint-Georges et al., 2013a; Cirelli et al., in press). Mimicry, establishing a relationship by

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