Pointing gesture in young children: Hand preference and language development

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This paper provides an overview of recent studies that have investigated the development of pointing behaviors in infants and toddlers. First, we focus on deictic gestures and their role in language development, taking into account the different hand shapes and the different functions of pointing, and examining the cognitive abilities that may or may not be associated with the production of pointing gestures. Second, we try to demonstrate that when a distinction is made between pointing gestures and manipulative activities, the study of children's hand preference can help to highlight the development of speech-gesture links.

Keywords: toddlers, gestural communication, pointing, handedness, speech-gesture system

Emergence of communicative gestures: Focus on pointing gestures

Pointing is a specialized gesture for indicating an object, event or location. Children start using pointing gestures at around 11 months of age (Butterworth & Morissette, 1996; Camaioni, Perucchini, Bellagamba, & Colonnesi, 2004), and this behavior opens the door to the development of intentional communication. One of the prerequisites for the production of pointing gestures is a shared experience between the signaler and the recipient of the gesture, that is, a simultaneous engagement with the same external referent, usually referred to as *joint attention* (e.g., Carpenter, Nagell, & Tomasello, 1998). While pointing is sometimes regarded as a "private gesture" (Delgado, Gómez, & Sarriá, 2009), whose main role is to regulate the infant's attention rather than to enable the latter to communicate with a recipient, a growing body of research suggests that the onset of pointing gestures reflects a newly acquired ability to actively direct the adult's attention to outside entities in triadic interactions (e.g., Liszkowski, 2005; Tomasello, Carpenter, & Liszkowski, 2007).

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Before describing some of the main physical features of pointing, we discuss the different communicative functions associated with pointing gestures, and the different social and cognitive skills they may or may not reflect.

Different communicative intentions

Several criteria are commonly used to characterize a gesture as intentional: (1) the behavior of the signaler has to be produced and directed toward a recipient, (2) the gesture is usually accompanied by visual-orienting behaviors, including gaze alternation between the recipient and the object or event being pointed at (this visual monitoring enables signalers to check the efficiency of the gestures, thus confirming their communicative intention), and (3) children are likely to repeat their gesture if they fail to produce the desired effect on their communicative partner (this persistence of the signal is also interpreted as a demonstration of intentionality). Researchers currently seem to agree over the intentional nature of the pointing gesture, but the latter encompasses different communicative functions that need to be examined if we are to see the whole picture.

In order to determine an infant's intention when he or she points toward a referent, researchers take several criteria into account. They focus on the accompanying features of the child's gesture (vocalizations, facial expressions, posture), the adult's behavioral reaction to the child's gesture, and the child's behavior following the adult's first reaction (see example below).On the basis of these different clues, they can generally distinguish between the two main functions of pointing gestures, named the imperative and declarative functions (e.g., Camaioni, 1997; Tomasello et al., 2007). Children use imperative gestures to obtain something from the adult, whether it is a specific action or a desired object. Declarative pointing gestures direct the adult's attention to a referent in order to indicate its existence and share interest in it. More specifically, according to Tomasello, Carpenter, and Liszkowski (2007), in *declarative expressive* pointing, children seek to point out some object, location or event to the adult that they consider interesting and worthwhile, while in *declarative informative* pointing, they seek to provide the adult with information he or she needs.

In some cases, it can be difficult to distinguish between the imperative and declarative motives behind children's pointing gestures. Most of the time, children's imperative gestures serve to request an object — indeed, these communicative behaviors are sometimes referred to as "request" gestures or "ritualized reaches" (e.g., Franco & Butterworth, 1996; Iverson & Goldin-Meadow, 2005), but imperative pointing can also be used to ask an adult to do something with an object (e.g., Colonnesi, Rieffe, Koops, & Perucchini, 2008). Thus, when an adult makes something interesting happen, such as activating a mechanical toy, how

should children's pointing be interpreted? Are they trying to share interest in the event with the adult or are they asking the adult to make that event happen again? The request behaviors that sometimes accompany children's gestures (e.g., whining, leaning forward, displaying negative affect) may help answer this question. Moreover, infants are very likely to display signs of dissatisfaction and repeat their pointing gesture if they do not achieve their goal the first time around. In the above example, if the child seems dissatisfied when the adult comments on the event of interest and does not activate the mechanical toy again, one can infer that the infant's motive was indeed imperative.

Above and beyond the different imperative and declarative motives behind children's gestures, the question naturally arises as to the nature of the cognitive abilities associated with these pointing gestures.

Cognitive abilities and pointing

The issue of the social and cognitive abilities involved in the use of pointing gestures has long been debated. Some authors support an instrumental reading of pointing, arguing that it develops through processes close to operant conditioning and that infants are simply seeking to obtain an object or a positive emotional reaction to the self from the adult (e.g., Bates, Camaioni, & Volterra, 1975; Moore & Corkum, 1994). By contrast, pointing is sometimes viewed as a cognitively complex gesture, reflecting infants' understanding of others' attention. Even when they are still in the early stages of development, children appear to be able to make references to external events or objects, and even to absent entities (Liszkowski, Schäfer, Carpenter, & Tomasello, 2009).

A parallel is sometimes drawn between these different theoretical accounts and the different functions of pointing. Basically, a rich mentalistic interpretation of declarative gestures, in which infants try to influence others' mental states, can be contrasted with a lean interpretation of imperative gestures, in which they try to influence others' behavior. There are several pieces of evidence supporting the dissociation between imperative and declarative gestures. Firstly, in development, the comprehension and production of imperative gestures precedes that of declarative gestures (Camaioni et al., 2004; Cochet & Vauclair, 2010-a). Moreover, gestures produced by children with autism seem to lack the declarative function (Camaioni, 1997; Camaioni, Perucchini, Muratori, & Milone, 1997), leading to the idea that imperative and declarative gestures may rely upon different cognitive abilities. The production of communicative gestures in nonhuman primates also tends to support the distinction between imperative and declarative functions (e.g., Leavens, Hopkins, & Bard, 1996). There have been very few reports of declarative gestures in apes, and they concerned individuals that had experienced close emotional ties

with humans and/or had been language-trained (see Leavens, 2009). It has therefore been argued that rearing history and emotional bonding with caregivers may play a role in the ability to develop declarative communication.

Adults' reactions can be experimentally manipulated in order to investigate the communicative intention and cognitive abilities involved in the production of infants' pointing. Adopting this approach, an experimenter reacted to 12-month-olds' pointing toward an interesting event in different ways (Liszkowski, Carpenter, Henning, Striano, & Tomasello, 2004). When the adult emoted positively toward the child without looking at the event, the infant showed signs of dissatisfaction, pointing less often across trials and repeating points more within trials. By contrast, infants were satisfied in the joint attention condition, that is, when the experimenter reacted to the event being pointed at and shared interest with the child. These results revealed that infants wanted the adult to integrate a specific referent into the interaction and share interest about it. In declarative situations, infants therefore expect more than just the other's attention and a display of interest toward them, contrasting with the instrumental view of pointing (e.g., Moore & Corkum, 1994). Experimental studies have highlighted the complexity of the social and cognitive skills involved in the production of declarative gestures (e.g., Liszkowski, 2005). For example, it has been shown that the ability to use declarative pointing is linked to the understanding of the other person's intentions, whereas this relation is not observed for imperative gestures (Camaioni et al., 2004).

However, the distinction between rich and lean interpretations of pointing gestures, depending on their functions, has been questioned by several researchers, who have proposed other alternatives. Leavens (2009) disproves the strict distinction between imperative and declarative pointing, arguing that every pointing gesture serves an instrumental function, at least in the early stages. According to him, infants seek to elicit specific affective behaviors from their caregivers rather than to share interest with adults about a referent. Consequently, declarative pointing would not demand higher cognitive abilities than imperative pointing. Moore and D'Entremont (2001) also argue that early declarative pointing is motivated egocentrically, representing attempts to receive a positive reaction to the self from the adult. The main evidence for this interpretation is that 12-month-olds point to events that the adult is already looking at. However, as previously exposed, these findings can be interpreted differently, children's intention being likely to elicit a reaction from the adult indicative of shared attention and interest (Liszkowski et al., 2004).

In the same vein, and though these statements still need further experimental investigations to be considered as clear empirical evidence, Southgate, van Maanen, and Csibra (2007) regard the pointing gesture as an interrogative act in all contexts: children point in order to obtain information about an object or

event. Pointing would not imply a cooperative motive — sharing interest or helping another person would not be an end in itself -, but rather a selfish need to learn about the environment. It has also been suggested that declarative pointing reflects the child's interest in the referent (the object or event being pointed at), without necessarily implying any involvement with the adult (Colonnesi et al., 2008).

Moreover, according to Tomasello, Carpenter, and Liszkowski (2007), imperative motives form a continuum from ordering to suggesting. In the former, the adult is understood to be a causal agent from whom the child can obtain what he/she wants, whereas the motive involved in the latter is less individualistic and more cooperative: the adult is regarded as an intentional agent who can decide whether or not to help the child.

Cochet and Vauclair (2010-b) have suggested that declarative expressive pointing may play an intermediate role in the development of communicative skills. They compared toddlers' communicative behaviors (pointing gestures, hand shapes, gaze patterns and accompanying vocalizations) in imperative, informative and expressive situations (Tomasello et al., 2007). Results revealed an opposition between imperative and declarative (both expressive and informative) gestures in relation to accompanying vocalizations — the latter were more frequent in the declarative situation than in the imperative one —, and also regarding hand shape, in that declarative gestures were mostly characterized by index-finger pointing, whereas imperative gestures were more frequently produced with the whole hand (see following section). However, their findings also highlighted a difference between informative pointing and the two other types of gestures with regard to hand preference (see the section concerning manual preference) and gaze pattern. Gaze alternation was more frequently coordinated with pointing in the informative situation, indicating that children were more likely to monitor the adult's attention to the external referent in this cooperative context. Declarative expressive pointing was therefore closer to imperative pointing, regarding visual behavior and hand preference, but closer to declarative informative pointing, regarding vocalizations and hand shapes, hence the hypothesis that expressive pointing represents an intermediate stage between imperative and informative communication (Cochet & Vauclair, 2010-b).

To briefly summarize, the distinction between imperative and declarative functions on the basis of cognitive differences is increasingly being called into question. It seems rather that various parameters come into the picture, including affective factors. Interestingly, we may also have to look again at the assumption of a causal relation between the development of cognitive skills and the production of pointing gestures, in favor of the hypothesis of mutual influence over development. Nonetheless, the psychological abilities that pointing may or may not reflect constitute a tricky issue for researchers. Hypothetical mental processes have to

be inferred from behavioral measures, as the cognitive processing involved in the production of pointing gestures cannot be directly measured. On the basis of these behavioral measures, we believe that there are at the very least motivational differences between imperative, declarative expressive and declarative informative pointing gestures.

Different hand shapes for pointing

Pointing gesture has traditionally referred to its canonical form: extended index finger and all other fingers tightly retracted (e.g., Blake, O'Rourke, & Borzellino, 1994; Butterworth, Franco, McKenzie, Graupner, & Todd, 2002; O'Neill, Bard, Linnell, & Fluck, 2005) and though index-finger pointing is the most commonly observed morphology, comparative investigations of pointing gestures have revealed cultural variations in hand shapes and in the degree of orientation of the forearm (prone vs. supine position). Forms encountered in some cultures are very rarely produced by English speakers, for example when the middle finger, not the index finger, is pointed toward a target (Wilkins, 2003). This is the reason why the narrow definition of pointing is usually replaced by a broader one that includes different hand shapes (e.g., Brooks & Meltzoff, 2008; Gullberg, de Bot, & Volterra, 2008; Krause & Fouts, 1997). Few studies have focused on the forms of pointing, but researchers mostly distinguished between whole-hand and index-finger pointing (Cochet & Vauclair, 2010-a, 2010-b; Leavens & Hokpins, 1999). The term "whole-hand pointing" was initially used in studies with nonhuman primates, as the latter rarely produce index-finger gestures. In human children, too, at least until the age of three years, the extension of the index finger does not seem to be a key feature of the pointing gesture. A study comparing the efficacy of various forms of pointing in an object-choice task (Lakatos, Soproni, Dóka, & Miklósi, 2009) showed that two-year-old children relied on the direction of the protruding body part, rather than on the direction of the index finger, to find a hidden toy. Three-year-old children, however, understood the meaning of the index finger and were also able to generalize from familiar pointing gestures to unfamiliar ones (e.g., pointing with the knee).

In addition to the cultural differences previously exposed, it seems that hand shapes are influenced by discourse context. Thus, on the basis of recordings made in natural situations, Kendon and Versante (2003) identified instances of pointing produced by Neapolitans, in order to investigate whether hand shapes differed according to the communicative context. These authors observed that conventional index-finger pointing (palm-down position) was more likely to be produced when the gesture was semantically important to the ongoing discourse, whereas pointing gestures with all the fingers extended seemed to convey the notion of nonsingularity

or nonindividuation. Moreover, pointing can be performed with different parts of the body, such as the hand, the mouth or the eyes, depending, for example, on the visibility of the referent or the formality of the context (Wilkins, 2003).

The morphology of pointing gestures thus appears to be influenced by cultural and contextual factors and it is reasonable to assume that the use of one particular hand shape rather than another involves some degree of social transmission. This hypothesis is supported by the difference observed in the morphology of pointing gestures between sighted and blind toddlers. Sighted children have been reported to use index-finger pointings most frequently and whole-hand pointings rarely, whereas blind children, who have not been confronted with the model of index-finger pointing, produced a vast majority of whole-hand pointings (Iverson, Tencer, Lany, & Goldin-Meadow, 2000).

Moreover, the distinction between different functions of pointing gestures has revealed an age-related increase in index-finger pointing at the expense of whole-hand pointing for declarative gestures, but not for imperative ones (Cochet & Vauclair, 2010-b). In an imperative situation, children kept on using whole-hand pointing, even though they were able to produce index-finger pointing, indicating that the distinction between hand shapes in infancy may depend on the context of use, as in adulthood, although the functions of the pointing gestures produced by children and adults remain different.

Origins of pointing gestures

The different functions and physical features of pointing gestures have theoretical implications regarding their origins, both at the ontogenetic and phylogenetic levels. In imperative pointing, the child uses the adult as a means of obtaining a desired object (e.g., Bates et al., 1975). The key determinant of this gesture is the inability to obtain the object by oneself, whether because of immature motor abilities in the case of human infants or because of captivity conditions in the case of nonhuman primates (Bard, 1990; Leavens, Hopkins, & Bard, 1996, 2005). Imperative pointing is thus rather self-centered and related mostly to the action of reaching toward an object. Consequently, and though there might be some alternatives to this hypothesis (see Carpendale & Lewis, 2006), it has been suggested that this gesture gains a communicative motive through social scaffolding, in a process known as *ontogenetic ritualization* (Tomasello & Call, 1997). This process enables a manual action to become progressively ritualized into a social and communicative gesture, on the basis of the adult's reactions to this specific action. Vygotsky (1988) had previously argued that all pointing gestures develop out of failed reaching, and though consistent with the imperative function of pointing, this hypothesis does not seem well-grounded with regard to declarative pointing.

It has been suggested that declarative gestures may be learned through social imitation during children's development, rather than being ritualized from reaching actions (Cochet & Vauclair, 2010-a, 2010-b). This hypothesis is supported by studies of nonhuman primates, as the production of declarative pointing has only been observed in chimpanzees that have experienced close relationships with humans (Leavens, 2009), and that were thus given the opportunity to imitate humans' communicative behaviors. However, further empirical investigations in human infants are needed to confirm the role of imitative abilities in the development of declarative pointing.

As there is no direct evidence of the learning processes through which the different kinds of pointing are acquired, researchers mostly have to base their arguments on behavioral cues. For example, the difference in hand shapes between imperative and declarative gestures supports the hypothesis of different origins for these pointing gestures. Imperative pointing is mostly characterized by whole-hand gestures whereas declarative pointing is more frequently produced with an extended index finger (Cochet & Vauclair, 2010-b). Moreover, these authors have found that the form of imperative gestures remains unchanged between 15 and 30 months of age, highlighting the close relationship between the structural characteristics of reaching actions and imperative pointing, even once children are able to produce index-finger pointing.

The different origins of imperative and declarative pointing gestures may also be reflected in different degrees of relationship with language development, as set out in the following section.

Relations with language development

Various studies have shown that gestures and speech are closely related in humans (Bates & Dick, 2002; Iverson & Thelen, 1999). This interconnection can be observed in people's natural conversation, as gestures frequently accompany discourse (Goldin-Meadow, 2003; McNeill, 1992). These co-speech gestures lend rhythm, emphasize speech and sometimes serve an iconic function, and although they have no direct linguistic function, they make the speaker's message easier to understand. A study using event-related potentials yielded neural evidence that both modalities are simultaneously integrated by the brain in order to understand an utterance (Özyürek, Willems, Kita, & Hagoort, 2007). Moreover, functional brain imaging studies have revealed that symbolic gestures and spoken words are processed by a common network of inferior frontal and posterior temporal regions of the left hemisphere (Xu, Gannon, Emmorey, Smith, & Braun, 2009) and that sign language activates Broca's area in the left hemisphere (e.g., Corina, San Jose-Robertson, Guillemin, High, & Braun, 2003; Emmorey, Mehta, & Grabowski,

2007). These results suggest that these areas, rather than being restricted to speech processing, have a modality-independent role in linking meaning with symbols.

The dynamic interplay between speech and gestures can be observed from the early stages of development onward. For instance, a study revealed that the emergence of babbling at around seven months of age is accompanied by an increase in repetitive right-handed activity (Locke, Bekken, McMinn-Larson, & Wein, 1995). More generally, gestural communication, notably pointing, provides a foundation for verbal communication, both predicting and facilitating the acquisition of language (e.g., Capirci & Volterra, 2008; Pizzuto & Capobianco, 2005; Rowe & Goldin-Meadow, 2009; Rowe, Özçaliskan, & Goldin-Meadow, 2008). The ability to combine two ideas in a single utterance first manifests itself in gesture-word combinations and the latter are thought to reflect a transitional stage in development, in that the age of onset of supplementary gesture-word combinations is correlated with that of two-word combinations (Ozçalişkan & Goldin-Meadow, 2005).

Recent findings suggest that the facilitative role of gestures in language acquisition may concern declarative but not imperative gestures. According to Camaioni and colleagues (2004), the use of declarative pointing is linked to the understanding of adults' intentions and is associated with the development of theory of mind abilities. These abilities are necessary for the emergence of speech, making declarative pointing gestures likely prerequisites for the development of human language. Other researchers also argue that some features of human language, namely social cognition and cooperation, are already reflected in toddlers' declarative pointing (Liszkowski et al., 2004; Liszkowski, Carpenter, Striano, & Tomasello, 2006; Liszkowski, Carpenter, & Tomasello, 2008). Moreover, when Cochet and Vauclair (2010-a) recorded pointing gestures produced by toddlers in spontaneous interactions at a daycare center, they found that declarative gestures were more frequently accompanied by vocalizations than imperative gestures were (Cochet & Vauclair, 2010-a), suggesting that these two types of pointing have different relationships with the vocal system.

In order to further investigate the links between gestures and the emergence of language, the second section of this review is devoted to the development of manual asymmetries.

Handedness and language development

Identifying lateralized patterns of communicative gestures is an indirect means of studying hemispheric lateralization for the control of these gestures (Kimura, 1973-a, 1973-b). Asymmetry in favor of the right or left hand suggests the functional dominance of the contralateral cerebral hemisphere, and given the left-

hemispheric specialization for language functions observed in the majority of humans (Knecht et al., 2000), studying the asymmetries associated with gestural communication may allow researchers to bring a new perspective on the relationship between gestures and language.

Studies investigating handedness have traditionally focused on manipulative actions, possibly because the notion of hand preference is so salient when talking about object manipulation. There are indeed many occasions in daily life when we can observe asymmetrical manipulation in the use of tools, whereas laterality for communicative gestures is less perceptible. People usually notice when the person next to them is writing with his/her left hand, but they rarely pay attention to the hand used by somebody pointing toward an object or event of interest. Laterality for communicative gestures is also more difficult to assess than handedness for manipulative actions, which is mostly measured through hand preference questionnaires. For these reasons, handedness in gestural communication has tended to be disregarded. However, in recent years, interest in the development of communicative gestures has grown considerably. Researchers have then started investigating asymmetries in the production of these gestures, especially at the time of language emergence.

Manual preference for pointing gestures

Several studies have reported a right-hand bias for pointing gestures in infants and toddlers (Bates, O'Connell, Vaid, Sledge, & Oakes, 1986; Blake, O'Rourke, & Borzellino, 1994; Cochet & Vauclair, 2010-a, 2010-b; Young, Lock, & Service, 1985). Although the spatial location of the referent influences hand choice for pointing, children are more likely to point to locations within their left visual field with their right hand than to locations in their right visual field with their left hand (Butterworth et al., 2002; Esseily, Jacquet, & Fagard, in press). Asymmetries in favor of the left hemisphere also apply to the *perception* of pointing gestures. It has been shown that pointing is understood significantly earlier for targets in the infant's right visual field than for ones in the left visual field (e.g., Carpenter et al., 1998).

In the course of development, the right-sided asymmetry for pointing gestures has been found to increase during the child's first twelve months of life (Blake et al., 1994). However, several researchers have failed to observe any increase in this right-handed bias between approximately one and three years of age (Bates et al., 1986; Cochet & Vauclair, 2010-a, 2010-b). The development of hand preference for gestures may vary according to factors other than age.

With this in mind, Vauclair and Cochet (submitted) set out to investigate the relationship between handedness for pointing gestures and lateralization for language. They measured hand preference for pointing in 46 toddlers aged 12–30

months and assessed their language level on the revised Brunet-Lézine scale (Josse, 1997), which allowed them to calculate a developmental quotient for language. Pointing gestures were found to be more right-handed in children with a high developmental quotient, namely in children who seemed to have higher learning abilities, compared to children with average language quotients. Event-related potential studies have previously reported a relation between increasing level of speech abilities and increasing involvement of the left cerebral hemisphere (Mills, Coffey-Corina, & Neville, 1993). According to Vauclair and Cochet (submitted), the fact that the latter is associated with a stronger right-handed bias for pointing gestures suggests the existence of a bimodal system in the left cerebral hemisphere, controlling both gestural and vocal communication.

Manipulative activities vs. pointing gestures

Research on right-handedness and language, as stated above, initially focused on manipulative actions. It found that 96 % of right-handers and 70 % of left-handers had left-hemispheric control for speech (Knecht et al., 2000), indicating that the relationship between handedness for manipulation and speech is, at best, indirect. In order to find out whether hand preference for pointing gestures is a better marker of hemispheric lateralization for language, we need to know the proportion of right-handed people for pointing gestures who present left-hemisphere specialization for language, and in turn, the proportion of left-handed people who are right-hemisphere dominant. Studies by Kimura (1973-a, 1973-b) have come closer to this issue, revealing a significant relationship between the cerebral dominance for speech (assessed with a dichotic listening task) and manual asymmetry. However, they focused on free movements that accompany speech, letting the question regarding intentionally produced pointing gestures still unanswered.

A more workable solution for investigating the relationship between the cerebral control of speech and pointing gesture is to compare patterns of manual preference between pointing gestures and manipulative activities. Researchers have reported a stronger degree of manual asymmetry for pointing gestures than for object manipulation (Bates et al., 1986; Cochet & Vauclair, 2010-b; Vauclair & Imbault, 2009). Moreover, in the study by Vauclair and Imbault (2009) with 123 infants and toddlers aged 10–40 months, a large proportion of the children who were left-handed or ambidextrous for object manipulation pointed with their right hand, whereas very few right-handers shifted to the left hand for pointing. The stronger involvement of the left hemisphere for pointing gestures supports the view that speech and gestures form an interconnected system, distinct from the system that is involved in purely motor activities. In nonhuman primates, communicative behaviors also show a stronger degree of population-level right-

handedness than manipulative actions (e.g., Hopkins et al., 2005; Meguerditchian & Vauclair, 2009; Meguerditchian, Vauclair, & Hopkins, 2010), which can be interpreted within an evolutionary framework about the origin of speech. The greater activation of the left hemisphere for communicative gestures in our closest cousins suggests that this left-lateralized gestural-vocal system may have a deep phylogenetic origin (Corballis, 2010; Meguerditchian, Vauclair & Hopkins, 2010).

The distinction between the different functions of pointing has yielded some interesting results regarding hand preference patterns. In an experimental study, three situations in day nurseries were designed to elicit imperative, declarative expressive and declarative informative pointing gestures (see above, page 130) in 48 toddlers (Cochet & Vauclair, 2010-b). A unimanual reaching task was also administered. The difference in the degree of manual preference between manipulative actions and pointing gestures was found to be strongest for informative pointing. The latter is produced to provide the adult with information he or she needs about a referent and may thus involve cooperation abilities (Tomasello et al., 2007). This result suggests that the development of cooperation, notably through the production of informative pointing, may play a role in the cerebral lateralization of human communicative behaviors. Bullinger, Zimmermann, Kaminski, and Tomasello (2010) have emphasized the especially cooperative nature of human communication, comparing the production of pointing gesture between chimpanzees and human infants. They observed that the chimpanzees pointed only when it was to their ultimate benefit, whereas 25 month-old infants pointed no matter who benefited. The authors have thus suggested that the informative motive, both at the ontogenetic and phylogenetic levels, may play and have played an important role in the emergence of linguistic communication.

To summarize the question of handedness, Figure 1 presents the results of four studies carried out in our laboratory, illustrating the need to distinguish (1) between manipulative activities and pointing gestures, and (2) between the different functions of pointing. This figure also emphasizes that research on the relationship between handedness and language development is made more difficult by methodological differences between studies. Gestures can include different communicative functions and hand preference can be assessed in either naturalistic or experimental situations. Regarding manipulation, handedness can be measured either through self-reported questionnaires or through direct observation of hand use, and using either unimanual or bimanual tasks. These different measures may lead to different patterns of handedness being recorded, as the degree of hand preference has been shown to vary according to task complexity (Fagard & Marks, 2000). Finally, handedness indices are not consistently used — some researchers only consider the total numbers of right- and left-handed gestures that are produced — and the distinction between right- and left-handers is not always based

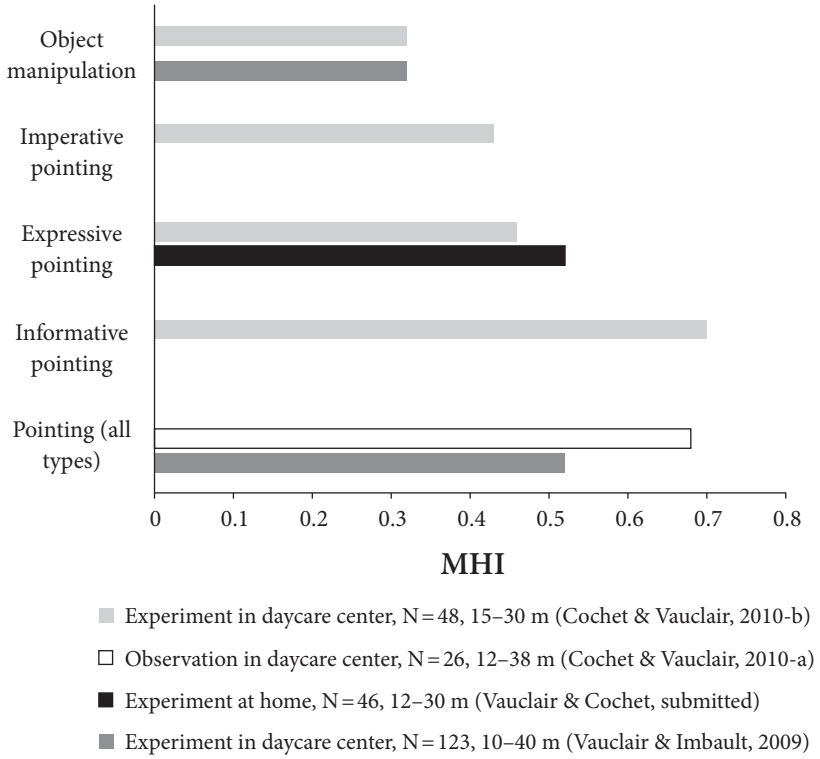

Figure 1. Mean handedness indices (MHI) associated with object manipulation and pointing gestures in different studies. Handedness index traditionally varies from −1 to 1. The positive sign here reflects right-hand preference and the absolute values the strength of hand preference.

on the same criteria across studies. While some researchers define an *a priori* hand preference threshold, without any statistical criterion (e.g., participants are categorized as right-handed if the handedness index is above 0.5), others rely on statistical tests to classify individuals as right- or left-handed (see Hopkins, 1999).

Manipulative activities, pointing gestures and language

Pointing gestures and manipulative activities present different patterns of hand preference, but a right-handed bias is observed for both activities. Gestural communication and object manipulation are therefore both lateralized to the left cerebral hemisphere, albeit to different degrees. The control of actions, gestures and language may thus involve complex, intertwined networks, rather than independent development. From the motor theory of speech perception (Liberman, Cooper, Shankweiler, & Studdert-Kennedy, 1967) to the more recent discovery of the

mirror neuron system (Di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992), the relationship between motor control and language has long been the focus of research.

The contiguous representations of hand and mouth in the cerebral cortex constituted one of the first arguments supporting the role of the motor system in the emergence of speech. More recently, researchers described seven stages in the evolution of language, emphasizing the key role of the motor system (Roy & Arbib, 2005). For these authors, articulated language evolved from grasping movements. These praxic movements then became adapted for communicative purposes and, with the parallel development of the vocal apparatus, protospeech emerged and gradually coevolved with protosign, leading to the emergence of the final stage: speech. In support of this scenario, Gonzales and Goodale (2009) demonstrated a positive correlation in adults between hand preference for precision grasping and language lateralization (measured by a dichotic listening test). However, the correlation they observed was moderate, which may imply that other processes come into play.

Moreover, if pointing gestures and speech do indeed originate from object manipulation, then how can we explain the different patterns of handedness observed between pointing gestures and manipulative actions (Bates et al., 1986; Vauclair & Imbault, 2009)? A longitudinal study investigating the relationship between language, manipulative actions and pointing gestures in 25 toddlers may go some way toward answering this question (Cochet, Jover, & Vauclair, submitted). Participants were observed once a month in day nurseries over a five-month period. Handedness was measured both with manipulative tasks and communicative tasks, including imperative and declarative pointing, and language level was assessed through a parental questionnaire. Measures of handedness for declarative pointing gestures were not correlated with those of handedness for manipulation, but the results revealed a significant correlation between hand preference for imperative pointing gestures and manipulative activities prior to the vocabulary spurt. Once the latter had occurred, this correlation became nonsignificant. This study illustrates the complex relationship between handedness and language development and underscores the need to take the different functions of pointing gestures into account.

Another study showed that handedness for manipulative actions significantly correlated with handedness for pointing gestures between 18 and 20 months and between 29 and 32 months, whereas correlations were not significant in the interim (Vauclair & Imbault, 2009). According to the authors, these two key phases, corresponding to the onset of the vocabulary spurt and the improvement in syntax, generate a specific cognitive load in the left hemisphere. The development of handedness in relation to language acquisition therefore seems to involve complex

interactions between manipulation and communication, but it is difficult to interpret these findings further, especially as language level was not directly measured in this study.

Pointing gestures and manipulative actions may share several properties that would explain the close interconnection in the brain between the control of manual action and language processing (e.g., Gentilucci & Dalla Volta, 2007; Willems & Hagoort, 2007). Both activities involve visuomotor control and the understanding of behaviors as being connected to targets through attention. Furthermore, it has been suggested that the lateralization of visuomotor control to the left hemisphere precedes the emergence of left specialization for praxis and language (Gonzales & Goodale, 2009). Moreover, manipulative and communicative activities may be both associated, albeit to different extents, with the development of an intentional and representational system that is also required for the control of articulate speech. Kendon (2009) for example argued that the emergence of language has been made possible through the transformation of praxic activity into "communicative actions", pointing and pantomiming. In this regard, the representational properties of the mirror neuron system may play a major role. These neurons, first discovered through single cell recordings in the ventral premotor cortex (area F5) of macaques (Rizzolatti, Fadiga, Gallese, & Fogassi, 1996), which fire during both the execution and the observation of actions, have been assigned a role in understanding others' intentional actions. Furthermore, it has been suggested that the role of the mirror neuron system evolved from the understanding of transitive actions to the understanding of intentional communication in humans (e.g., Capirci & Volterra, 2008). The mirror system may thus be the ideal neural substrate for the emergence of theory of mind and language (e.g., Fadiga & Craighero, 2007; Gentilucci & Dalla Volta, 2008; Rizzolatti & Arbib, 1998).

Conclusion

The different studies described in this review highlight the role played by gestural communication, especially pointing gestures, in the control of intentional and referential communication. We present a number of arguments, some drawn from our own studies, in favor of the notion that pointing gestures are part of a broader and multimodal communicative system. We go on to demonstrate the relevance of studying hand preference for pointing gestures in order to fully investigate the development of communicative behaviors and improve current understanding of the nature of speech-gesture links. One consequence arising from this perspective is the need to distinguish between object manipulation and pointing gestures, as the degree of handedness may differ between these two activities. Lastly, we point

out the complex relationship between actions, gestures and language in the course of development and emphasize that studies of pointing gestures should take several dimensions (e.g., functions, hand shapes, accompanying vocalizations) into account in order to pinpoint these multifaceted interconnections.

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