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2

Social Interaction in Infancy

Tobias Schuwerk and Hannes Rakoczy

C2.S1

2.1 Introduction

C2.P1

The way we, adult humans, see and treat each other is very special. It is fundamentally different from our perception of, and interaction with, the rest of the natural world. Most fundamentally, we perceive each other[1] as subjects and not just as objects. There are several aspects to this peculiar conceptual framework of seeing each other as subjects (which comes under many names, including 'folk psychology' or 'Theory of Mind'): cognitive, emotional, moral, and many more. Here, we focus, from a developmental perspective, on what arguably are the most foundational conceptual elements of this framework: seeing individuals as rational intentional agents who have subjective perspectives on the world, who act for and are generally susceptible to reasons, and with whom one can thus enter into relationships of 'shared intentionality' in communication and cooperation.

C2.P2

In this chapter, we will describe milestones of the development of this conceptual framework (which, following established if unfortunate usage, we will mostly call 'Theory of Mind') in infancy (for a schematic overview, see Fig. 2.1). In Section 2.2, we will review evidence on the very early development, in the first weeks and months of life, of remarkable forms of social interaction and social perception that, though not yet manifestations of Theory of Mind themselves, may present important precursors. In Section 2.3, we will then describe the emergence of the first forms of Theory of Mind towards the end of the first year of life. At this stage, children begin to operate with a basic teleological stance: they understand that persons act in the pursuit of goals, and on the basis of perceptual access to facts. This fundamentally changes the way they interact with others, and opens up completely new avenues for communication and cooperation.

In Section 2.4, we address the question of when more refined and sophisticated, fully meta-representational forms of Theory of Mind emerge. In fully meta-representational Theory of Mind, one does not only ascribe access to values (goals) and facts to others, and explain their actions on that basis. Rather,

[1] … and, potentially (inter-individual and cross-cultural differences are huge in these respects) other animals and non-organic agents (robots, etc.) as well. For simplicity's sake, we will ignore these complications and largely focus on human interpersonal cognition and social interaction.

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C2.F1

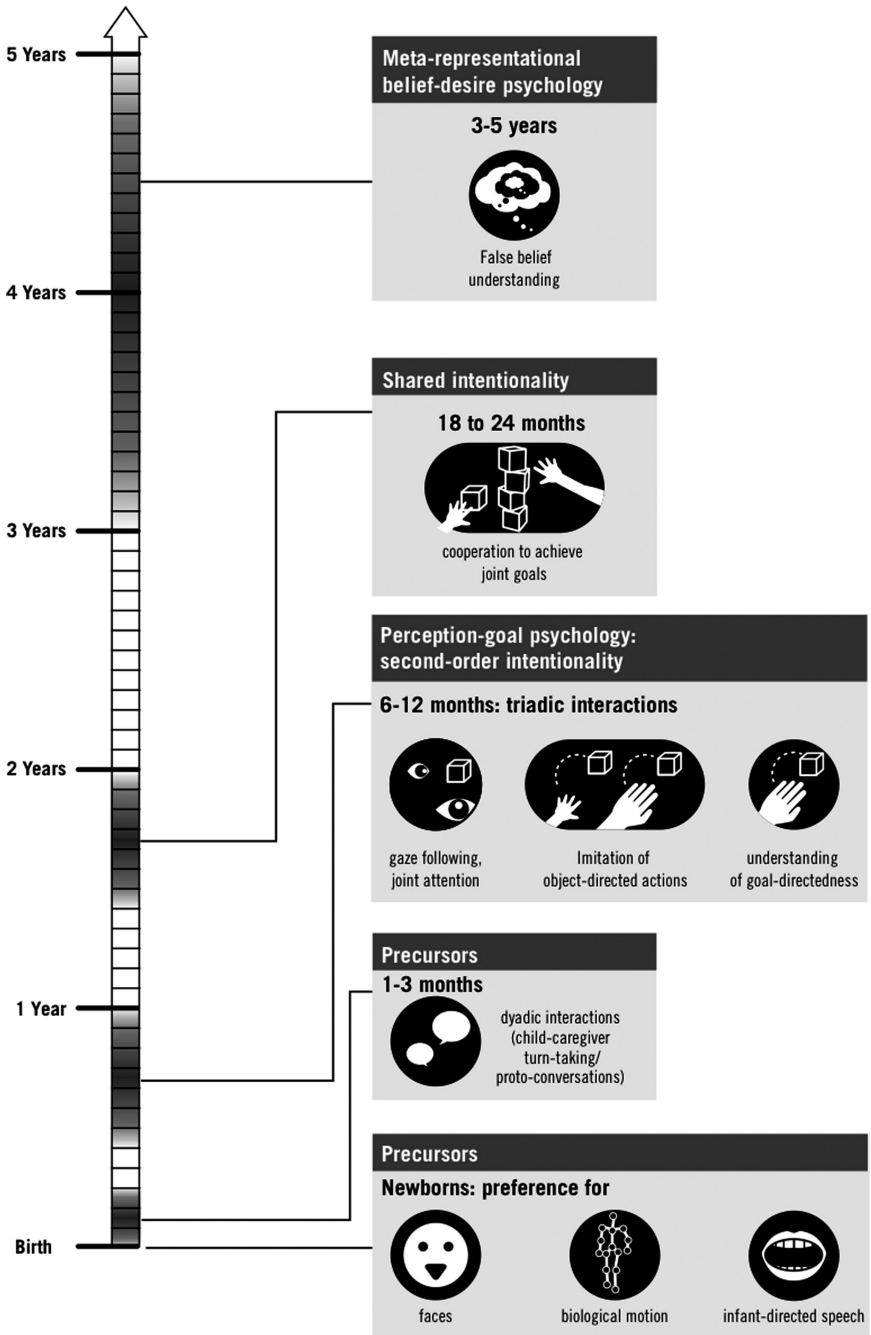

Fig. 2.1 Schematic overview of developmental milestones of social interaction in infancy

one explicitly represents what and how others subjectively represent, potentially misrepresent, the world cognitively (beliefs) and conatively (desires)—which is why this framework also goes under the rubric 'belief–desire psychology'. Until
C2.P3 recently, it was generally believed that children develop this more refined framework only much later, on the basis of linguistic and other experience. But new evidence from the past 15 years has suggested that even infants may be capable of full-blown meta-representation. In light of a serious replication crisis regarding these findings, however, it is currently rather unclear when, in fact, sophisticated, meta-representational Theory of Mind emerges. After reviewing the debates, the evidence, and the replication crisis, we conclude by summarizing the most important lessons, open questions, and future directions.

C2.P4 ## 2.2 Precursors

C2.S2 ### 2.2.1 Sensitivity to social information

C2.P5 From birth onwards, infants show a remarkable preference for social stimuli—that is, for any sensory information that is elicited by another individual (such as appearance, movement, sound, or smell). Faces carry rich information that is crucial for social interaction. Already, newborns within their first hour after birth show a high sensitivity to faces.[2] When presented with a moving stimulus minutes after birth, they turn their eyes and head towards this stimulus. Yet, when the pattern displayed on these stimuli resembles key features that constitute a face (cf., Omer et al., 2019), newborns are most responsive to it (Goren et al., 1975; Johnson, 2005). They also have a preference for direct gaze (Farroni et al., 2002) and, within the next weeks, they begin to actively focus on key central regions, such as the eyes, when visually scanning faces (Haith et al.,1977). Furthermore, infants very efficiently detect faces in natural scenes. Those aged 3–12 months quickly detect and preferably look at faces embedded in visually complex settings (e.g. a person standing in a garden full of colourful flowers; Kelly et al., 2019).

C2.P6 Another feature that differentiates animate agents from the rest of the world is biological motion. When viewing dots moving on a screen, already very young infants prefer those displays in which the movement pattern of the dots resembles animate motion patterns (e.g. as if the dots were attached to the joints of a walking human) over the same display when it is presented upside down or over randomly moving dots (Bertenthal et al., 1984; Simion et al., 2008).

[2] Recent evidence suggests that even in the third trimester, fetuses show such a preference (Reid et al., 2017). Yet, a number of substantial methodological issues have been identified with this study (Scheel et al., 2018).

C2.P7 When adults talk to infants, they intuitively modify linguistic and prosodic features of their speech, a process presumably aiding early language acquisition. Infants, in turn, seem to be biased to preferentially attend to this form of speech. Cooper and Aslin (1990) documented a preference for such infant-directed speech already in newborns. A recent multi-lab replication study confirmed this effect in over 2,500 infants between 3 and 15 months of age (the ManyBabies Consortium, 2020).

C2.S3 ### 2.2.2 Early forms of interaction

C2.P8 The above-reported examples demonstrate that, from birth on, infants orient towards social stimuli. When observing these actions in context with the caregiver's behaviour, it becomes evident that already within the first months of life early forms of interaction emerge. Caregivers elicit orienting reactions (and other actions infants are able to perform) and vice versa. Such reciprocal and contingent patterns of attention orienting, arm and leg movements, smiling and vocalization are termed 'child–caregiver turn-taking', or 'proto-conversations' (Bigelow, 1998; Brazelton et al.,1974; Trevarthen, 1979). Importantly, infants expect contingency in the behaviour of others. When the caregiver is instructed to suddenly remain unresponsive (e.g. stop smiling or cooing back at the infant), they react disturbed, sometimes try to reinitiate reciprocity but finally withdrawing from the caregiver ('still-face effect'; see Adamson & Frick, 2003).

C2.P9 A special form of early interaction is imitation, which presumably plays a key role in social learning (Piaget, 1952). Imitation of simple object-directed actions emerges at around 6–8 months of age (Barr et al., 1996). Whether newborns already imitate is a subject of ongoing discussion. For a long time, it has been assumed that shortly after birth infants imitate movements such as mouth opening or tongue protrusion (Meltzoff & Moore, 1977). However, a rigorous longitudinal replication study suggested that this conclusion is based on methodological artifacts like inadequate control conditions or analyses, or small outlier-biased samples (Oostenbroek et al., 2016; but see Meltzoff et al., 2018).

C2.P10 To conclude, infants seem to be tuned to orient towards the social world. More importantly, they already distinguish between animate agents and inanimate objects, and are more responsive towards animate agents (Legerstee, 1992). This provides an optimal basis for learning about others through experience. Moreover, from early on, infants interact with the social world through contingent turn-taking (for a review on potential underlying mechanisms, see Markova et al., 2019). These constitute essential pre-conditions towards an understanding of the mind (cf. Gergely & Watson, 1999; Jones & Klin, 2013).

C2.S4

2.3 The emergence of basic ('perception-goal') folk psychology

C2.P11 What we thus see in the first months of life are impressive forms of social sensitivity and interaction, and probably important precursors and foundations of more complex forms of social cognition. But, taken by themselves, they do not necessarily involve much social understanding (of others' mental life and subjective perspective) yet.

C2.P12 However, from the second half of the first year of life, we witness the emergence of a class of new phenomena that mark the first forms of true folk psychology. While infants engaged in dyadic interaction either with objects (in exploration and play) or with people (in proto-conversation) before, now begins triadic interaction: children interact with others in reference to (about) external objects—for example, in joint attention (e.g. the child follows and shares an adult's attention to an object) or imitation (the child reproduces another agent's intentional action on an external object) (Carpenter et al., 1998). According to the standard interpretation, this indicates the ontogenetically first and most basic form of second-order intentionality[3] (or folk psychology, or Theory of Mind): some grasp of others' intentional ('aboutness') relations to the world. Mature folk psychology operates with concepts for two classes of intentional states (termed 'propositional attitudes'): cognitive ones, paradigmatic beliefs, that aim at representing the world as it is; and conative ones, paradigmatic desires, that aim at representing the world as it subjectively ought to be. Fully fledged rational action explanation involves reference to pairs of intentional states of each type (e.g. 'He pressed the switch because he *wanted* to open the door and *thought* the switch was the door opener'). Mature folk psychology thus often comes under the name 'belief–desire psychology'.

C2.P13 The more basic folk psychology of infants does not necessarily involve a fully meta-representational appreciation of the subjectivity of beliefs (that represent things and states of affairs in certain subjective ways that may be accurate or inaccurate) and desires yet. But it does involve an understanding of basic cognitive states (in particular, perception) and basic conative states (in particular, goal-pursuit). It is thus often termed 'perception-goal' folk psychology (Wellman, 2011).

C2.S5

2.3.1 Understanding perception

C2.P14 A number of phenomena indicate that infants begin to understand something about perception towards the end of the first year of life (at the latest). At this time,

[3] Intentionality here refers, in the technical sense of the term as used in philosophy and cognitive science, to the aboutness of mental states that have semantic content, paradigmatic perception, belief, desire, intention, etc. (Brentano, 1874/1973; Searle, 1983).

they start following the gaze of others (Carpenter et al., 1998a). Gaze-following as such is widespread in the animal kingdom. Taken by itself, it is not necessarily indicative of any social-cognitive understanding, but could simply reflect low-level attention orienting mechanisms. Human gaze-following is special, though, from early on: infants do not just, in an orienting response, follow an onlooker's gaze (e.g. to a barrier) but actively try to find out what it is the other person is seeing or looking at (e.g. by crawling around barriers and looking for potential referents; Moll & Tomasello, 2004). Even more convincingly, infants only follow another agent's line of sight when they think that this agent can actually see (but not, for example, if she turns her head while wearing a blindfold; Brooks & Meltzoff, 2002).[4]

C2.P15 Numerous phenomena in infants' interaction and communication with others, as well as in their looking behaviour, suggest that they engage in what is often termed 'Level I perspective taking': understanding what others can and cannot see, or have and have not seen, even if that deviates from one's own perspective (Flavell et al.,1981). In many looking time and naturalistic interaction studies, children were confronted with situations in which another agent faced with several objects, all visible to the child, made ambiguous actions of referring to or reaching towards one of the objects. Crucially, the agent had visual access to only one of the objects, not to the other. In these studies, children during their second year expected that the agent would refer to or grasp only those objects that were perceptually available to them (e.g. Moll & Tomasello, 2006; Poulin-Dubois et al., 2007).

C2.S6

2.3.2 Understanding goal-directedness

C2.P16 Infants thus operate with a basic notion of perceptual perspectives on the world—arguably a precursor to fully fledged concepts of belief and other cognitive intentional states. Regarding conative intentional states, infants reveal a basic grasp of goal-directedness and intentional action. Corresponding evidence comes from studies on interaction, imitation, and looking time. Influential looking-time studies suggest that infants attribute goal-directedness and rational action to animated geometrical figures much like adults do in animations made popular by Heider and Simmel (1944).[5] In one study, an agent repeatedly jumped over an obstacle to reach a given goal. In the test phase, this agent then sometimes took the same detour on its way to the goal when the obstacle had been removed. Infants found the agent's apparent irrationality surprising and looked longer to the detour

[4] These early capacities for gaze-following have been found, in some studies, to be continuous with, and predictive of, later Theory of Mind (Brooks & Meltzoff, 2015; Kristen et al., 2011).

[5] An example of the original stimulus material that illustrates the phenomenon can be found at: https://www.youtube.com/watch?v=VTNmLt7QX8E

event than to an event in which the agent took the—novel but now rational—direct path (Gergely et al., 1995).

C2.P17 In their spontaneous interaction with others, infants also reveal sensitivity to goal-directedness and intentional action. For example, when another agent fails in pursuit of some goal (e.g. accidentally drops an object she needs that then falls out of her sight), children spontaneously offer instrumental help (e.g. pick up and hand over the object), but they do not do so in analogous situations in which the agent does not pursue the goal in question (e.g. when she voluntarily throws away the object; Warneken & Tomasello, 2006). Similarly, they distinguish between actions that fail, either because the agent was unable (wanted to but could not) or unwilling (did not even want to) to perform it successfully. For example, when an adult earnestly tries to give them some toys but repeatedly fails, they wait more patiently than when the adult teases them by almost handing them the object and then withdrawing it—even if the superficial movement characteristics of the two (unwilling versus unable) acts are closely matched (Behne et al., 2005).

C2.P18 Imitation, finally, presents a rich body of evidence for infants' understanding of goal-directed intentional action. Infants begin to imitate object-directed actions by others from around 9 months of age (Tomasello, 1999). Imitation, taken by itself—and in the wide sense of behavioural reproduction—remains highly ambiguous regarding the underlying social-cognitive capacities; it could reflect mere mimicry, emulation, or other superficial mechanisms. More specific and sophisticated forms of imitation, though, are less ambiguous. They indicate that infants do not just blindly reproduce superficial behaviour but understand and imitate intentional actions.

C2.P19 One case is differential imitation of the same superficial behaviour that is either marked as intentional action or as mere accidental behaviour. When children see an agent perform a behaviour (e.g. dropping an object into a box), they imitate when the agent marked it as intentional and goal-directed ('There!'), but not when she marked it as mere accident ('Oops!') (Carpenter et al., 1998). Imitative response to failed attempts is another case. When infants see an agent unsuccessfully trying to achieve a goal, they then do not imitate the failed means, but perform the action properly and successfully themselves—indicating that they understood what the agent was up to and not just how she superficially behaved (Meltzoff, 1995). Lastly, infants engage in what has been termed 'rational imitation'. They systematically imitate very exactly when they see the behavioural means an agent used as ends in themselves; and imitate creatively and efficiently when they think that the behavioural means used by the other agent were only means to an end, and they themselves have better means at hand to reach the same end. In a famous study on this phenomenon, infants saw an agent perform an instrumental action (switch on a light) with unusual means (pressing the switch with the head). In one condition, the agent had her hands free and thus could have used them (licensing the inference that using the head was an end in itself and not just a means to an end).

In the other condition, her hands were unavailable under a blanket (licensing the inference that the bizarre head-use was just a means to an end). In their imitation, infants used their hand to switch on the light in the hands-unavailable condition, but the head in the hands-free condition, indicating that their imitative responses were based on a rich rational interpretation of the agent's action in terms of means and ends (Gergely et al., 2002).

C2.S7

2.3.3 Shared intentionality

C2.P20 Infants thus operate with a rudimentary understanding of others as intentional agents (related to the world cognitively via perception and conatively via goal-directed intentional action). This constitutes the most basic form of individual intentionality of second order—that is, not only being an intentional agent oneself (first order), but understanding others and oneself as intentional agents (second order). Such simple individual second-order intentionality seems not to be restricted to humans, but also to be part of the cognitive repertoire of great apes, perhaps other non-human primates, and birds (Kaminski et al., 2008). Human infants, however, may be special in the following sense: from the time they develop perception-goal folk psychology, they do not just operate as individual intentional agents who understand others and themselves as such. Rather, they transcend individual intentionality (first and second order) and engage in shared or collective we-intentionality (Tomasello & Rakoczy, 2003).

C2.P21 Though it is a notoriously contested question in philosophy and psychology as to how best to analyse shared intentionality (e.g. Bratman, 1992; Searle, 1995), the basic phenomenon is intuitively clear: two people dancing tango together are not the sum of two individuals each dancing by themselves, not even when each understands about the other what she is doing individually. When A intends 'I tango' and B intends 'I tango', and A understands 'B intends to tango' and B understands 'A intends to tango', this may at most amount to dancing side by side but not to dancing together. What makes for a real duet is the shared intention, 'we dance together'.

C2.P22 Infants engage in such shared we-intentionality from the second year on. The clearest type of evidence comes from their cooperative actions with others, both instrumental and playful. Children from around 18 to 24 months coordinate with others in order to achieve joint goals, communicate appropriately, engage in division of labour and roles, and even indicate a sense of commitment (when we act together, we are committed to the pursuit of the joint goal, and to each other, in ways that go beyond mere individual goal pursuit; Warneken et al., 2006). From a comparative and evolutionary point of view, one possibility is that shared intentionality marks the ontogenetic beginnings of uniquely human social cognition. Whereas individual intentionality and basic forms of individual intentionality

of second order are evolutionarily more ancient, and thus more widespread and developing in analogous ways in humans and other primates, the paths separate when it comes to shared intentionality, which only humans develop and which lays the ground for the subsequent development of culture, language, and all culturally and linguistically mediated forms of higher cognition (e.g. Tomasello, 2014).

C2.S8

2.4 The emergence of fully fledged belief–desire folk psychology

C2.P23

That basic forms of individual intentionality of second order (perception-goal psychology) and shared intentionality develop in infancy is a widely accepted consensus. When it comes to the question of when and how more sophisticated forms of Theory of Mind—in particular, meta-representational belief–desire folk psychology—develop, things get much more complicated (for an overview of the main complexities, see, e.g. Rakoczy, 2012).

C2.S9

2.4.1 Standard picture of Theory of Mind development

C2.P24

Until 15 years or so ago, the standard picture used to be the following: infants and toddlers operate with basic Theory of Mind that allows them to track what others have informational access to (perception) and what they are aiming at (goals). But this falls short in fundamental ways from the true and fully fledged meta-representational Theory of Mind that operates with propositional attitude concepts, such as belief and strong notions of subjectivity and perspective, and that develops later, from around age 4. One way to illustrate the fundamental difference is with recourse to different forms of perspective taking: infants and toddlers engage in so-called Level I perspective taking. Cognitively, they understand that different agents can perceive different things ('I see something that you cannot see', or vice versa). Conatively, they understand that different agents may have different aims or preferences ('You like broccoli, I like crackers', Repacholi & Gopnik, 1997). However, they are not yet capable of Level II perspective taking. That is, they cannot yet understand *how* agents represent situations in fine-grained propositional ways: that different agents—cognitively—can see one and the same state of affairs differently, and can thus possibly misrepresent reality (false beliefs), and that—conatively—people can have desires that are not only different but mutually incompatible (Perner & Roessler, 2012).

C2.P25

This sophisticated and fully fledged meta-representational Theory of Mind, according to the old standard picture, only develops in protracted ways on the basis of linguistic and other socio-cultural experiences, as well as domain-general cognitive processes such as executive function. Evidence comes from several

sources: first of all, children begin to master all kinds of explicit verbal tasks that tap a meta-representational grasp of (mis-)representation from around age 4. Such tasks include the famous standard false-belief task in which children have to predict or explain how an agent will act on the basis of her mistaken belief about reality (Wimmer & Perner, 1983), appearance–reality tasks in which children have to contrast what an object is and what it visually appears to be (Flavell et al.,1983), and Level II perspective-taking tasks in which children have to distinguish how a given situation looks differently from different viewpoints (Flavell et al., 1981). Children do not only come to solve all these and conceptually related tasks around the same age, but performance is highly consistent and correlated across tasks, reinforcing the interpretation that they all tap the same underlying conceptual capacity (Perner & Roessler, 2012).

C2.P26 Regarding the role of executive function, many studies document that executive functions and meta-representational Theory of Mind (indicated in performance in false-belief and related tasks) are strongly correlated both synchronically and longitudinally, such that executive function at time 1 predicts Theory of Mind at time 2 but not vice versa (Carlson et al., 2004; Carlson & Moses, 2001; for a meta-analysis, see Devine & Hughes, 2014). With regard to the relation of language and Theory of Mind, the evidence is multifarious (for review, see, e.g. Astington & Baird, 2005; Milligan et al., 2007): first of all, general language proficiency and Theory of Mind are strongly correlated. More interestingly, and going beyond mere correlation, studies with deaf children speak more directly for a causal role of language in Theory of Mind development. Deaf children who acquire native sign language at home, and thus show normal linguistic development, also develop Theory of Mind in typical ways; deaf children of hearing parents, in contrast, acquire language in much delayed ways, and are equally delayed in their Theory of Mind (Peterson & Siegal, 1999). Additional converging evidence comes from speakers of Nicaraguan Sign Language. This relatively new sign language has undergone substantial linguistic complexification in the past few years, and speakers of the language who acquired it in its earlier (and thus grammatically less complex) stages are severely delayed in their Theory of Mind relative to speakers of later generations (with much more complex grammatical structure; Pyers & Senghas, 2009). Finally, experimental evidence from training studies corroborates this picture. It shows that specific experience with language, both pragmatic, semantic, and grammatical, boosts Theory of Mind development (e.g. Lohmann & Tomasello, 2003).

C2.P27 The standard theoretical interpretation of this developmental pattern used to be framed in terms of conceptual change. On the basis of language as a potential medium for conceptual thought, and on the basis of domain-general capacities such as working memory and executive function, new conceptual structures emerge, and children between 2 and 4 slowly progress from the more basic perception-goal folk psychology to the fully fledged meta-representational belief–desire folk psychology (e.g. Perner, 1991).

C2.S10 ### 2.4.2 New empirical wave and early competence accounts

C2.P28 More recent theoretical accounts, however, question this standard interpretation, and new evidence challenges its empirical foundations. Nativist accounts have been the most elaborate opponents to the standard picture (e.g. Baillargeon et al., 2010; Carruthers, 2013; Leslie, 2005). According to nativism, meta-representational Theory of Mind, being largely innate, is in operation very early in ontogeny, in any case much earlier than assumed by the standard picture. The fact that children fail standard false-belief and related tasks until age 4 does not reveal any conceptual competence deficits (because there are no such deficits). What these failures indicate are merely performance limits: children fail these tasks not because they require meta-representational Theory of Mind, but because they have other extraneous task demands (verbal, inhibitory control, etc.) that make the tasks artificially difficult. Once such tasks demands are out of the way, children should well be able to bring to bear their precocious conceptual competence and pass Theory of Mind tasks. Another class of accounts, dual process theories, assume that humans operate with at least two kinds of processes of Theory of Mind reasoning: Type I processes develop early, operate in implicit and largely unconscious fashion, and embody some Theory of Mind propensity to represent mental states in basic ways that go beyond mere perception-goal psychology (even if not incorporating fully fledged belief–desire psychology yet). In contrast, Type II processes, basically corresponding to explicit Theory of Mind according to the standard picture, develop later, based on language and executive function, and operate in explicit and conscious ways (Apperly & Butterfill, 2009). Both nativist and dual process accounts share the assumption that there are precocious Theory of Mind capacities in place much earlier than assumed by the standard picture, and these should become visible in implicit tasks stripped of verbal and other performance factors.

C2.P29 A growing body of evidence from the past 15 years seems to empirically support this assumption. Studies with various types of non-verbal implicit tasks point to Theory of Mind capacities in children way before age 4, sometimes as young as 1 year of age (for review, see Baillargeon et al., 2010; Scott & Baillargeon, 2017). In *violation-of-expectation* (VoE) adaptations of standard false-belief tasks, infants have been found to look longer to events in which an agent acts inconsistently with her (true or false) beliefs than to those in which she acts belief-consistently (Onishi & Baillargeon, 2005). In *anticipatory looking* (AL) studies, children from 1 to 2 years have been found to look in anticipation to where an agent will go or act in accordance with her (true or false) belief (Southgate et al., 2007; Surian & Geraci, 2012). *Interaction-based* studies have suggested that children from 18 to 24 months of age, when spontaneously interacting and communicating with others, take into account what the other agents (truly or falsely) believe, and adapt their actions accordingly (Buttelmann et al., 2009; Knudsen & Liszkowski, 2012; Southgate et al., 2010).

C2.S11 ## 2.4.3 Replication crisis

C2.P30 The standard picture that fully fledged meta-representational belief–desire folk psychology develops at around 4 years of age is underpinned by a solid and often replicated empirical basis. The most elaborate quantitative evaluation of this effect was provided by Wellman et al., (2001). In their meta-analysis of published false-belief tasks (by that time, spanning 178 studies and over 4,000 children), they found that, largely independent of task manipulations or country of origin, children become able to attribute false beliefs between 2½ and 5 years of age.

C2.S12 ### 2.4.3.1 Replicability and validity of non-verbal implicit tasks

C2.P31 In contrast, the empirical basis supporting early competence accounts is much less solid. To date, there are about 30 published studies showing false-belief competency in children before their third birthday (Scott & Baillargeon, 2017). Further, these studies come from relatively few labs and often have small sample sizes (e.g. 10–25 infants per condition in the between-participants design of the most prominent studies by Buttelmann et al., 2009; Onishi & Baillargeon, 2005; Southgate et al., 2007). It is important to note that small sample sizes are also an issue of the previously published standard false-belief tasks and that this alone does not justify discarding findings from either task type. However, several recent studies point at three major issues with non-verbal implicit tasks that have not been observed in standard tasks.

C2.P32 First, positive evidence from each of the three non-verbal measures is now faced with several published failed replication attempts (e.g. VoE paradigms: Dörrenberg et al., 2018; Powell et al., 2018; Yott & Poulin-Dubois, 2016; AL paradigms: Burnside et al., 2018; Dörrenberg et al., 2018; Wiesmann et al., 2018; Kulke et al., 2018a; Schuwerk et al., 2018; Interaction-based paradigms: Crivello & Poulin-Dubois, 2018; Poulin-Dubois & Yott, 2018; Priewasser et al., 2018). Further, a survey revealed that additional unpublished non-replications existed (Kulke & Rakoczy, 2018). The replication attempts varied in how closely they adapted the original procedure (some used the original stimuli, some produced their own versions, many received advice from the original authors). The fact that all these studies, covering a broad spectrum from direct to conceptual replications (for a classification framework, see LeBel et al., 2018), failed to replicate the original findings speaks against the potential objection that those non-replications are attributable to poor implementation of the original procedures.

C2.P33 Second, measures of early false-belief competence seem to have poor construct validity. For example, the combination of results of the replication attempts of several tasks reported by Powell et al. (2018) suggests that performance in VoE paradigms might be driven by the infants' less sophisticated ability to track another's state of knowledge based on her perceptual access, rather than by false-belief understanding (for further alternative explanations, see Heyes, 2014; Perner &

Ruffman, 2005). Out of several attempts to replicate AL measures, a replication attempt of a paradigm employed by Low and Watts (2013) stood out because it was successful in a sample of adults (Kulke et al., 2018b). However, in a follow-up study, Kulke et al. showed that once potential confounds are removed from the stimulus material (an imbalance in the cueing of one of the two potential target locations), this paradigm also cannot be replicated (for a similar case, see Phillips et al., 2015). Additionally, the interaction-based paradigm by Buttelmann et al. (2009) is challenged by recent evidence supporting an alternative explanation of infants' task performance. The infants' performance in a control condition introduced by Priewasser et al. (2018) was incompatible with the interpretation that their helping behaviour is guided by the appreciation of the experimenter's false belief about the toy's location. Rather, it was in line with the non-mentalistic explanation that it is guided by the experimenter's likely goals in this particular situation (that the experimenter wants to find the toy in this hide-and-seek-like situation).

C2.P34 Third, non-verbal implicit tasks lack convergent validity. Several recent studies found minimal or no systematic correlations between the three most prominent task types (and even within different tasks of the same type) that are all supposed to tap the same underlying construct (Dörrenberg et al., 2018; Kulke et al., 2018a, 2018b; Poulin-Dubois & Yott, 2018; Powell et al., 2018; Yott & Poulin-Dubois, 2016). Thus, whereas findings from numerous variations of explicit false-belief tasks converge on the conclusion that explicit false-belief understanding develops at around 4 years of age (Wellman et al., 2001; see also Perner & Roesler, 2012), no such pattern emerges for early false-belief understanding (for a meta-analysis, see Barone et al., 2019).

C2.P35 In sum, recent studies question the theoretical claim of false-belief understanding in infancy. Positive findings are challenged by a growing body of non-replications. Further evidence suggests that in non-verbal implicit tasks, infants may track another person's state of knowledge, based on her perceptual access (distinguishing between information access knowledge and lack thereof), but that they don't consider this person's false belief. Lacking inter-task correlations suggest that the available task types do not measure one common phenomenon. Further, a recent meta-analysis by Barone and colleagues (2019) showed that a large variance of performance in these tasks remains unexplained. In other words, we do not entirely know yet what these tasks are measuring. Moreover, this meta-analysis identified a substantial publication bias in the literature currently available.

C2.S13 #### 2.4.3.2 Interpretations of puzzling findings

C2.P36 So, what can be concluded from this complex and puzzling emerging picture? Is there a full-blown Theory of Mind in infancy? Two extreme positions frame the current debate (Baillargeon et al., 2018; Poulin-Dubois et al., 2018). On the one

hand, one extreme position concludes 'yes, there is a Theory of Mind in infancy', as documented by the original studies. Unsuccessful replication attempts constitute false-negative findings. This claim often entails post-hoc explanations of why these replication attempts failed (Baillargeon et al., 2018). On the other hand, the opposite extreme position concludes 'no, there is no such thing as full-blown Theory of Mind in infancy', and the original findings might be false positives. The documented publication bias (Barone et al., 2019; Kulke & Rakoczy, 2018), as well as high exclusion rates based on flexible criteria (Schuwerk et al., 2018) and flexible parameter selections (e.g. Rubio-Fernández, 2019), may be seen as support for this interpretation.

C2.P37 Yet, neither of these extreme positions is conclusively justified at the moment. It is not convincing to draw strong conclusions about a full-blown, maybe inborn Theory of Mind in infancy based on relatively few studies, and to explain away non-replications with mostly methodological post-hoc arguments. At the same time, it is unjustified to discard the positive evidence and conclude that there is no Theory of Mind in infancy based on the recent failed replication attempts. In sum, the unsatisfying but, in light of the current empirical situation, most accurate answer to the question of whether infants already have a Theory of Mind is: 'We don't know yet' (Poulin-Dubois et al., 2018). Current theory building seems to be 'on hold' until the empirical situation is better understood.

C2.S14 #### 2.4.3.3 Lessons learned and ways forward

C2.P38 The positive effect of this current situation is that it advances the field by changing its research culture. Against the background of the replication crisis in psychological science in general and its probable sources, particularly small sample sizes, publication bias, and questionable research practices (Button et al., 2013; John et al., 2012; Nosek et al., 2012; Open Science Collaboration, 2015), new ways to improve developmental psychological science are being explored. One such constructive response is the ManyBabies initiative (MB, https://manybabies.github.io; Frank et al., 2017), which tackles the above sources of poor replicability. This initiative aims at replicating influential experiments in developmental psychology through the cooperation of many labs, and thus, with large sample sizes, transparent methodological decisions throughout the project, and the publication of results irrespective of their outcome, it provides a framework for the promotion of reproducibility, best practices, and theory building in developmental research (Frank et al., 2017).

C2.P39 In the second project of this initiative, 'MB2: Theory of Mind in infancy', original authors and authors of replication attempts form a consortium to conduct multi-lab replication studies of the three most influential paradigms (VoE, AL, interaction-based). This project advances the field by bringing together researchers with very different theoretical positions, in the spirit of 'adversarial

collaboration' (Mellers et al., 2001), to hold debates as objective and unbiased as possible. Controversies between original authors and authors of non-replication studies can get heated and bear the potential to stir up personal resentments. This leads to discussions that bind resources but do not advance the field. To be successful, researchers in the MB2 Consortium have to try to let passion and enthusiasm in what they do fuel challenging and confrontative but factual discussions. Additionally, by the implementation of general best practice recommendations combined with consensus on discipline- and paradigm-specific procedures, the MB2 Consortium establishes new standards for methodological rigour (Frank et al., 2017; The ManyBabies Consortium, 2020; see also Rubio-Fernandez, 2018). The project is currently piloting stimuli of the first wave of a multi-lab conceptual replication attempt of AL paradigms. Once the stimuli are optimized to fulfil certain preconditions (e.g. when pilot data suggests that the stimuli sufficiently elicit anticipatory looking and that the infants track the agent's stage of knowledge, indicated by a differentiation between the true belief and ignorance of the agent), a worldwide call to participate in the attempt to replicate false-belief-congruent anticipatory looking will be made. To conclude, in this situation of contradicting empirical evidence, in which also meta-analyses have proven to be unhelpful (Barone et al., 2019; Van Elk et al., 2015), the MB2 project promises to shed light on the question of whether, and if so to what extent, infants already understand others' minds.

C2.S15

2.5 Summary

C2.P40

From birth on, infants are astonishingly well equipped to get in touch with the social world. Basic forms of social interaction shape the relationships between infants and their caregivers from early on and become continuously more sophisticated throughout the first year of life. By the second year, infants have acquired important developmental milestones of simple (perception-goal) folk psychology and shared intentionality. Around their fourth birthday, children develop a full-blown explicit meta-representational Theory of Mind, an essential foundation for successful social interaction. This standard picture of the development of social interaction has been questioned by research suggesting false-belief competence earlier in infancy. Yet, developments of recent years remind us to be careful in drawing strong conclusions on what infants can and cannot do on relatively thin empirical grounds. As in the case of neonatal imitation (and probably also fetal face preference, see Scheel et al., 2018), recent replication studies challenge the early competence view. Looking to the future, collaborative approaches implementing methodological rigour promise to generate solid knowledge on the development of social cognition and social interaction in infancy.

C2.S16

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