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Understanding the perception-action processes involved in social interaction: the case of manual search behavior for hidden objects in toddlers

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Understanding the perception-action processes involved in social interaction: the case of manual search behavior for hidden objects in toddlers

SUMMARY

Understanding the perception-action processes involved in social interaction is a recent topic of research. In the present article, we focus on a striking toddlers' failure in a manual search situation for hidden objects, namely the C-not-B task. We argue that the C-not-B task is a microcosm that can provide an insight into the nature of mechanisms that underlie behavioral decision making in a manual search task. Three theoretical approaches are discussed. In the cognitive perspective, a simple heuristic that use limited information drives the search behavior of toddlers in the C-not-B situation. In the embodied perspective, the C-not-B error is grounded in sensorimotor interaction with the environment. In the social perception-action perspective, the C-not-B error results from the emergence of a social unit of action in which partners share attention, intention and action.

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Introduction

In everyday life, we have to face a major pragmatic problem: to select between actions that are currently possible. Traditional cognitive theories propose that the brain addresses this question by first creating symbols which appropriately represent the real world, and these symbols are later manipulated in order to obtain a solution to the problem. By performing computations over internal representations of the world, humans thus are assumed to select appropriate actions. These theories are based on hypotheses that posit mental representations as carriers of information about the environment of the agent (Markman & Dietrich, 2000). Mental representations are invoked as mediators between the environment and the behavior. Along these lines, Johnson-Laird (1988) has proposed that (1) the brain is an organ for building internal representations of the external world; (2) much of human behavior is based on mental representations of the world. Viewed in this light, the brain can be seen as a processing system that generates behavior thanks to a full-blown mental model of the environment, from which it derives a detailed plan of action. In such a perspective, the brain is the controller of the body. Some authors even postulate that the entire purpose of the brain is to produce movement. Thus, Wolpert, Ghahramani and Flanagan (2001) consider that all sensory and cognitive processes may be viewed as inputs that determine future motor outputs. Mental representations and computational processes are used to determine motor commands given desired actions.

In the traditional framework of cognitive psychology, the ability to generate situation-appropriate action thus implicates the construction of mental models that contain rich information about the nature of the external world. This typical view is actually increasingly challenged by a view that stresses the additional importance of self-organizing processes in human behavior. Indeed, various studies have led to a revaluation of the way we look at the processes governing action selection in the context of a real-world environment. Whereas cognitive neuroscience considers the brain as a commander of behavior, embodied and situated cognition proposes that cognition and behavior emerge from the bodily interaction of an organism with its environment (cf. van Dijk, Kerkhofs, van Rooij, & Haselager, 2008). Embodied cognition is an approach that embeds the individual's mind in a body. This theoretical perspective stresses the importance of the bodily dynamic and environmental context, and in this way draws attention to the behavioral- the perception-action – context of cognition (Keijzer, 2002). In this theoretical framework, the success of behavior in the daily life can be explained without the need for high-level world modelling, planning, and decision-making. Thus, Haselager, van Dijk and van Rooij (2008) argue that because of a natural fit between organism and environment, organisms can be "ignorant successful" in their "user-friendly" environments most of the time. As these authors said: "*From this perspective, a creature can be seen as a repertoire of behavioral dispositions and the environment selects from it. A creature is inclined, in virtue of its bodily possibilities and its history of interactions with its environment, to respond to stimuli in specific ways without high-level thought or planning. Perception, action, and the world are structurally coupled to form a temporarily stable behavioral pattern that is functional with respect to the task*" (Haselager, van Dijk & van Rooij, 2008, p. 284). On this view, the focus shifts from accurately representing an environment to continuously engaging that environment with a body so as to stabilize coordinated patterns of behavior that are adaptive for the agent (Beer, 2003). Self-organizing processes thus are considered as central mechanisms for the emergence of search behavior.

Developmental science is making substantial progress towards understanding the mechanisms underlying the manual search behavior for hidden objects in early childhood.

Developmentalists now widely agree that many factors potentially influence manual search behaviour in children. The planning of reaching movements in a manual search task is generally thought to be a problem of decision-making. Since Piaget (1954) search behavior thus has been considered a planning behavior involving mental representations and specific motor intentions. In this perspective, the search behavior is guided by the child's conscious representation of the location of the hidden object. Hence, manual search situations are considered deliberative preferential choice tasks. However, the situated and embodied nature of some types of search tasks is highlighted by some authors (e.g. Thelen, Schöner, Scheier, & Smith, 2001). Indeed, various studies suggest that some search errors observed in childhood are grounded in sensorimotor interaction with the environment.

In the present article, we focus on an intriguing error that has been observed in toddlers presented with a three-location search task involving invisible displacements of an object, namely the C-not-B task (cf. Rivière & Lécuyer, 2003). In this task, a child is shown the experimenter's hand that contains a toy. The experimenter's hand then successively disappears under the three cloths (A, B, then C). The examiner silently releases the toy under the second cloth (B). The hidden object makes a bump in the B cloth that covers it. In this task, the child thus has to issue a reaching movement based on a cue indicating the correct location of a hidden object (i.e. the bump under the B cloth), and to ignore irrelevant information (i.e. the motion of the experimenter's hand that disappears under the C cloth). Children aged from 2.5-year-old fail this task by being strongly biased toward the last cloth that the experimenter's hand passes under, and this has been labeled the C-not-B error. It should be noted that introducing a delay before the C-not-B task search increases the success level in toddlers (Rivière & Lécuyer, 2003). The motion of the experimenter's hand in space appears to have made the task difficult because toddlers had no problems inferring that a lump under a cloth indicates the existence of an object without actually having watched an object be hidden there (Rivière & Lécuyer, 2008). Toddlers' failure in the C-not-B task is a phenomenon that can be approached by different theoretical perspectives.

Cognitive perspective

The C-not-B error: A simple heuristic for search behavior?

Humans can consciously perform highly complex calculations to compare options. However, in the real world, people often make a decision on the basis of a single piece of discriminating information. Chase, Hertwig and Gigerenzer (1998) assumed that many human decision-making can be described by simple algorithmic process models, namely heuristics. These heuristics do not tax people's limited computational resources and exploit specific features of the environment. Decision making via simple heuristics fits the bounded rationality model. This theoretical framework highlights the cognitive limitations of the information gathering and processing powers of human decision making. From this perspective, our minds are designed to work in environments where information is often costly and difficult to obtain, leading us to use fast and frugal heuristics when making many decisions. (Todd, 2007).

The key feature of bounded rationality is a limited information search, which requires some kind of stopping rule (Chase, Hertwig & Gigerenzer, 1998). Indeed, in contrast to the 'rational' decision strategies in which information is integrated, heuristics do not bother searching through and integrating information about other alternatives. In this view, people do not have to be able to make complex calculations in order to behave adaptively. They simply have to use successful heuristics. This idea meshes well with the proposals of the ecological rationality model. This conceptual framework stresses the environmental context in which reasoning takes place in order to understand everyday human inference (Chater, Oaksford, Nakisa, & Redington, 2003). Reasoning that may appear poor in an ecologically invalid laboratory context may be highly adaptive in the natural environment. Hutchinson and Gigerenzer (2005) thus pointed out that what have been viewed as maladaptive biases in humans are in fact the by-products of rules that make adaptive sense in an appropriate environment. Hence, a heuristic is neither good nor bad per se: some are better than others in any given environment.

In the real world, in which environmental parameters are uncertain, simple heuristics have an advantage in making decisions quickly and with little information. These heuristics can produce appropriate actions without explicit rule following or calculations. Such an account can explain why people are often successful in achieving many of their everyday goals, in spite of a limited ability to reason or act for good reasons sanctioned by a normative theory (Evans & Over, 1997). Therefore, as noted by Chater et al. (2003) much actual research on everyday judgment and decision making endorse the emphasis on the environment, and on cognitive limitations, and on finding simple algorithms that work well in the real environment.

Some failures observed in childhood in manual search tasks can be described with heuristics. In the C-not-B task, toddlers are unable to take into account information other than the motion of the experimenter’s hand in programming their search strategy, despite the availability of obvious salient cues. Moreover, the delays between the opening of the experimenter’s hand after he removed it from the last cloth and the beginning of the child’s reaching gesture are relatively small (an average of 2 s), a fact that argues in favour of the hypothesis that C-not-B error production was the result of impulsive responding. Taken together, theses results suggest that a simple heuristic that use limited information drives the search behavior of toddlers in the C-not-B situation.

More precisely, the C-not-B error could be explained by the simple rule that, in everyday life, a good way to find an object after it has been moved is simply to reach in the direction where it, or its container, was last seen. This search strategy often turns out to be pertinent in a wide range of real-world situations. Thus, despite a possible failure, this strategy exhibits an ecological rationality in that it often allows a person to reach their goal under the constraints of limited time, information, and computational capacity. As we have previously mentioned, the key feature of bounded rationality is a limited information search, which requires some kind of stopping rule (Chase, Hertwig & Gigerenzer, 1998). In the C-not-B situation, the stopping rule for an information search may be very simple: take the best cue (i.e. the location where the experimenter's hand attracted the child's attention, namely C Cloth) and ignore the rest (i.e. the bump in B Cloth). This cognitive algorithm is not rational in a formal sense because rather than using all pieces of information it bases its choice on a single piece of information.

From a normative point of view, a 'rational' decision strategy in which information is integrated should be preferred to a one-reason decision-making strategy in order to maximize the accuracy of choices. In the C-not-B situation, however, it is not the normative consideration of accuracy that apparently guides toddlers in information selection but a one-reason decision-making strategy that needs only one cue to make a decision. Such a strategy is frugal in its use of information because it bases its decision on a single feature. It is also fast in its execution because it does not bother searching through and integrating information about other alternatives. The psychological mechanism underlying the failure of toddlers in the C-not-B task may thus be a simple, fast, and robust “ignorance” strategy. Fast and frugal strategies that use subsets of available cues have been shown to be successful in many environments (cf. Hutchinson and Gigerenzer, 2005, for review). Indeed, some heuristics not only economize on cognitive effort but also perform relatively well compared to rational benchmarks (Karelaia, 2006).

We argued that the motion of the experimenter’s hand in the C-not-B task grabbed the attention of the toddlers, leading to attentional focus (Rivière & Lécuyer, 2003, 2008). An adaptive explanation could be provided for the predominant use of motion information in the C-not-B task. More precisely, evolutionary framework could explain why, in the C-not-B task, salience from experimenter hand motion attracts attention in a different way to salience evoked from the bump in the C Cloth. Indeed, the motion of a stimulus is an event which has special significance for the visual system. The onset of the motion is known to capture attention (Connor, Egeth & Yantis, 2004). It may also play a crucial role in the detection of prey and predators (Wagner, Kautz & Poganiatz, 1997). Due to higher adaptive value, salience from the motion of a stimulus may be a strongest cue for attracting attention than other stimuli, e.g., a visual cue.

It is an open question whether heuristics are learned or innate. Hutchinson and Gigerenzer (2005) have hypothesized that humans’ ability to learn through experience makes them more readily adopt simple heuristics than other animals that are more rigidly programmed and where natural selection alone is responsible for the adaptation. In contrast, evolutionary psychologists proposed that domain-specific psychological mechanisms were shaped by natural selection to meet the challenges of physical and social environments that were recurrently faced by our ancestors (Keenan & Ellis, 2003). These mechanisms are designed to take only certain kinds of information from the world as input, and then generate as output a behavior that is directed at solving an adaptive problem. By optimizing the speed and accuracy of decisions and the rate of receiving rewards for correct choices, some heuristics may provide a clear evolutionary advantage to the subjects that use them. Gigerenzer and Brighton (2009) proposed that the point of reasoning is to allow people to deal with the everyday world, rather than conforming to rational norms. In their view, inference should be assessed in terms of its success in solving ecologically relevant problems in natural environmental contexts. A particular behavior can be unjustified by the norms of classical rationality and, at the same time, ecologically successful. In this framework, the search pattern demonstrated by toddlers in the C-not-B task can be viewed as adaptive: objects are sought in the direction where they, or their container, were last seen because they are more likely to be there. Although this strategy cannot be normatively justified using classical rational norms, it is in the real world generally reliable and efficient for achieving one's goals. From this theoretical perspective, the C-not-B phenomenon is not an error. In contrast, it can be viewed as a functionally correct choice in some environmental contexts.

Embodied approach

The C-not-B error: A perception-action coupling?

In the original study involving the C-not-B paradigm (Rivière & Lécuyer, 2003) 14 children (mean age = 2 years 5 months) with spinal muscular atrophy (SMA), a hereditary neuromuscular disease that results in severe motor impairments, and 14 chronologically age-matched controls were presented with the C-not-B task. Results show that SMA children found the hidden object in this particular task. Moreover, the performance of the SMA group was significantly superior to that of the healthy control group. We proposed that a motor routine prevents healthy toddlers from expressing an appropriate behavioral response in the C-not-B task. This motor routine is the motor tendency to search for things in the direction where they, or more exactly their containers, were last seen. Such a prepotent motor response may preempt full consideration of a visual clue indicating the correct location of the hidden object. This hypothesis is supported by a recent study (cf. Rivière & Lécuyer, 2008). In this experiment, we provided some evidence to suggest that toddlers' performance on the C-not-B task can improve dramatically by putting a 200-g weight on their arms. Indeed, this simple manipulation had a significant impact on performance, with 77% correct performance as compared with 44% in the standard condition. We explained these findings by suggesting that the success in the C-not-B task of toddlers with additional arm weights could result from a disruption of automatic hand movement that is triggered by sensory signals, namely salient features of the C-not-B task. Observing a substantial reduction in production of the C-not-B error when children's body parameters were altered experimentally led us to view this search error as a phenomenon that is intrinsically embodied.

In our analysis, toddlers' failure in the C-not-B task arises from built-in biases in the perceptual-motor system. In this view, the motor routine at work in the C-not-B task is an automatic behavioral response that links sensory cues to motor action. We hypothesize that it is associated with a shift of attention. Indeed, this motor routine appears to be triggered by attentional processes that focus on the place where the experimenter's hand was last seen. Because such a direct perceptual-motor link appears not to be subject to voluntary control, it might trigger a response that is inappropriate in a given task context. Thus, the C-not-B error may be the product of the processes that take a hand to a location in visual place - memories of actions, and the close coupling of looking and reaching. The motor routine underlying the C-not-B error is about associating reach movements with specific contextual cues. It is a context-dependent motor memory. By this interpretation, C-not-B error may derive more from an entrenched motor routine than from a representational failure. Indeed, perception-action couplings can prevent the application of higher order processes and the production of representation-driven performance. Such analysis suggests that search behavior is embodied in the intrinsic physicality of an individual and is intensely dependant on the surroundings. In this account, some search errors have more to do with the dynamics of the human motor system than with a mental representation implied in the goal of reaching for a particular location. Rather than being purely abstract, decision making in manual search tasks thus may be shaped by bodily states and the body's relation to the environment.

The idea that human decision making must be understood in the context of its relationship to a physical body that interacts with the world fits well with the viewpoint of embodied and situated cognition. Indeed, this theoretical framework holds that cognitive processes are deeply rooted in the body's interactions with the world (Wilson, 2002). According to Williams, Huang and Bargh (2009) higher mental processes are intimately related to perceptual and motor processes, such that the mind's activities cannot be divorced from the physical, bodily context in which they occur. From this point of view, the principal aim of a situated agent is to take action appropriate to its circumstances and goals, and the physical properties of an agent's body is a resource as important as cognition in service of this objective (Beer, 2000). In this perspective, cognition evolved in service of action. Indeed, abilities such as sophisticated cognitive decision making did not appear from thin air but evolved within an ancestral context of real-time interactive behavior (Cisek, 2007). Thus, Brass and von Cramon (2008) argue that cognitive control functions evolved from hand-motor control and are therefore tied to the hand-motor system. In their view, the close proximity of cognitive-control-related activation and hand-motor-control-related activation in the intraparietal sulcus supports this hypothesis. According to these authors, the functional neuroanatomical overlap of cognitive control and hand-motor control suggests that cognitive control can be understood as a kind of abstraction from hand-motor control.

The two experiments on the C-not-B error reviewed in the present section reveal the extent to which child thought is constrained by physical properties of the human body, and the body's relation to the environment. Indeed, these experiments suggest that the physical execution of the child decision in some manual search tasks do not occur in addition to making the decision. In contrast, the reaching movement is at the heart of the decision making process. The process of decision making would already be the process of retrieving the sensory and motor information that would directly mediate the reaching movement. Thus, perception-action couplings can have pervasive influences upon child judgement and behavior. In particular, perception-action couplings are capable of influencing a child's behavioral control, and response selection in manual search tasks. In the traditional framework of cognitive psychology, the brain viewed as a device for manipulating arbitrary symbols is the organ of decision making. However, human beings are physical agents who act within physical space. Hence, the physical dimension of the human being should not be ignored when investigating decision making processes in manual search tasks. In these tasks, human decision making previously thought to be highly abstract now appears to be yielding to an embodied cognition approach.

Social perception-action perspective

The C-not-B error: A social unit of action?

The C-not-B task requires the child to interact with an adult partner. Hence, the perception-action processes at work in this situation should be studied in connection with social interaction. Marsh, Richardson, Baron and Schmidt (2006) proposed a perspective that retains both integrally social features (e.g. involves interaction) and yet adequately exploits the current state of knowledge regarding the ecological properties of perception-action. From this perspective, an important question is how toddlers understand the C-not-B task and the experimenter's expectations. This question is related to the ongoing debate about the role of shared intentionality in cooperative interactions. As said Warneken, Chen, & Tomasello (2006): "*In interactions involving shared intentionality, participants do not just react to one another's actions, but they have intentions toward the other's intentions; they must understand the intentions of the other and incorporate them into their own intention*" (Warneken, Chen, & Tomasello, 2006, p. 641). At this point of discussion, the question that arises is the next: what is shared in partners engaged in the C-not-B task?

Some authors suggested that a system combine nonverbal behavioral cues displayed by people around us (gaze direction, head orientation, gestures, and postures) to process the direction of social attention. Thus, Perret and Emery (1994) suggested that the superior temporal region of the macaque brain that responds to conjunctions of eye, head, and body position detects the direction of another individual's social attention. In line with this perspective, Langton and Bruce (2000) argued that directional signals provided by the hands are analyzed automatically to compute the whereabouts of another individual's focus of interest. Similar joint attention effects have been reported for the observation of grasping postures (e.g., Fischer, Prinz, & Lotz, 2008). One way of interpreting the C-not-B error would suggest that this specialized and automatic system that extracts intention-related directional information affects decision making processes in toddlers presented with the C-not-B task. Indeed, toddlers' failure in this search task may be mediated by the effect that certain social signals can exert on a viewer's spatial attention. Given his importance to social life, the fact that experimenter's hand motion had precedence over other visual stimuli in mediating toddlers' response selection is not surprising. Because of the value of such cue in daily life, this source of information carries the most weight in the decision process. Hence, observing the experimenter performing a hand movement in direction to the last cloth biases toddlers towards selecting the same action.

In this perspective, joint attention plays a crucial role in the production of the C-not-B error. However, joint attention can evolve into joint action in which partners coordinate their actions to achieve the goal. Complementary actions are important components of joint-action situations where two people are engaged in the same task. Although participants in the C-not-B task do not directly act together to achieve a common goal, the character of the situation might nonetheless facilitate the execution of a complementary action. Thus, in the C-not-B task, toddlers may adjust their action to the adult partner in order to help him to achieve the goal that visibly he is unable to achieve alone. In fact, toddlers may understand the C-not-B task as involving two roles and be motivated to cooperate with the experimenter and repair his failure to find the hidden object. In other words, toddlers comprehended their own and the adult's actions as interconnected parts of a joint activity toward a joint goal. Thus, the C-not-B error may result from the toddlers' tendency to act on behalf of others. In support to this interpretation, a close connection between the production of the C-not-B error and the development of prosocial behavior can be observed.

Indeed, some studies suggest that early forms of prosocial behavior appear in toddlerhood. Thus, Warneken, Chen and Tomasello (2006) established that 24-month-olds were proficient cooperators with an adult partner in a variety of tasks that require the joint activity of two people. Brownell, Svetlova and Nichols (2009) recently demonstrated that 25-month-olds voluntarily share valued resources with others, whereas younger children do not. By the end of the second year of life, children thus become more sensitive to another's needs. The prosocial disposition to interact in cooperative activities with an adult partner develops in toddlerhood. It could be argued that the development of prosocial behavior during this period plays a crucial role on how toddlers perceive and act in the C-not-B situation. The child may misinterpret the adult's intentions and motivations and perceive behavioral and situational cues as complementary action requests. More precisely, the child may perceive the adult's action as both a failure to find the hidden object and an invitation to execute a reaching movement toward the last cloth in order to retrieve the object. Thus, his or her own part of the task may be complementary to the adult's part of the task in order to perform a joint action. Toddlers may cooperate by adjusting their individual performance to the performance of the adult experimenter to achieve the common goal. In this view, prosocial motivational processes are an ingredient in toddlers' choice to reach for the last cloth. To sum up, toddlers' failure in the C-not-B task could be induced by pragmatic misinterpretation and explained by joint action. From this perspective, the C-not-B error paradoxically may be indicative of the early emerging prosocial behavior.

In this interpretation, toddlers may infer that the absence of the object inside the experimenter's hand after he removed it from the last cloth is an accidental action and not an intentional action. Thus, toddlers may lack agentive understanding of the C-not-B situation. As Pacherie and Dokic said: "*A genuine agentive understanding of action requires a representational redescription of the action, where goals and means are represented separately, thus making it possible to represent agents as directed towards goals independently of the means employed and to understand the intentional relation of the agent to the goal as the mediating force that explains the means-end sequence* (Pacherie & Dokic, 2006, p. 107). In the absence of an agentive understanding of the C-not-B situation, toddlers may misperceive the experimenter's action and focus on the last place visited by the experimenter's hand.

Humans appear to have a unique ability and motivation to share goals and intentions with others (Dominey & Warneken, 2009). Recently, Tomasello, Carpenter, Call, Behne and Moll (2005) proposed that the capacity for joint action depends on the capacity to share intentional states. It could be argued that toddlers' intention and behavior in the C-not-B task closely depend on the intentions and behavior of the adult partner. More precisely, toddlers' reaching could occur in response to inferences about the adult's intentionality and desires. This motivation to share mental states including goal-based intentions may form the basis of the joint action observed in the C-not-B task. Indeed, the child may misperceive the experimenter's intentions behind object-directed actions and may execute a complementary action on the basis of this misinterpretation of the experimenter's desires.

CONCLUSION

Young children are generally prone to errors when solving manual search tasks. Indeed, different types of search failure occur in infancy and toddlerhood in object retrieval tasks involving a manual search. In the present article, we focus on an intriguing error that has been observed in toddlers presented with a three-location search task involving invisible displacements of an object, namely the C-not-B task. We argue that situation such as C-not-B task is a microcosm that can provide an insight into the nature of mechanisms that underlie the manual search behavior in infancy and toddlerhood. Three theoretical approaches are discussed. In the cognitive perspective, a simple heuristic that use limited information drives the search behavior of toddlers in the C-not-B situation. In the embodied perspective, the C-not-B error is grounded in sensorimotor interaction with the environment. In the social perception-action perspective, the C-not-B error results from the emergence of a social unit of action in which partners share attention, intention and action. These perspectives are not mutually incompatible. Rather, it seems that a deeper understanding of the C-not-B error can only be achieved if we investigate how low-level processes interact with higher-level mechanisms.

According to Knoblich and Sebanz (2006), reassessing perception, action planning, and motor control in the light of their potential social roots might reveal that functions traditionally considered hallmarks of individual cognition originated through the need to interact with others. Recently, Topal, Gergely, Miklosi, Erdohegyi and Csibra (2008) proposed that infants' perseverative search errors can be ascribed to an interpretative bias induced by communicative cues. It should be noted, however, that some authors are strongly opposed to this proposal (e.g. Spencer, Dineva, & Smith, 2009). In spite of the fact that such interpretation is controversial, it testifies the importance of social dynamics to explain human behavior. We argue that both cognitive and embodied approaches of the C-not-B error involve insufficient social interaction. One way of interpreting the C-not-B error would suggest the emergence of a social unit of action characterized by the fact that experimenter's action constrains and creates reciprocating toddlers' action toward the implied common goal of the dyad. This social perspective highlights the cooperative character of the C-not-B error and account for it in intentional terms. Indeed, considering toddlers' belief about the intentions of the adult partner permits to account for the cooperative dimension of the C-not-B error. Such an analysis yield insights into the nature of the different kinds of sharing involved in manual search tasks between the adult experimenter and the child. If we are to attain a comprehensive understanding of children's failures in these tasks, it appears to be essential to identify the corresponding shared intentional representations.

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