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Feature or location? Infants and adults adopt different strategies to search for a hidden toy in an ambiguous task

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ABSTRACT

Evidence suggests that infants and adults attribute different importance to certain object properties when performing object-directed actions. Namely, infants tend to rely on information about an object's location, whereas adults are more likely to base their actions on its features. In this study, we tested whether the strategic choices of infants (aged 13 months) and adults would be modified by the context of the demonstration. Participants watched as an experimenter hid a ball under one of two different coloured containers, using either a communicative or a non-communicative manner. Then, the locations of the two containers were changed out of sight of the participant. During the test, participants were encouraged to look for the ball under one of the containers. We found that adults were more likely to follow a feature-based strategy than infants. However, there was no effect of the context of the demonstration, suggesting that communication may play different roles in encoding object properties and directing overt behaviour.

1. Introduction

Humans live in environments filled with various kinds of objects of different properties. Object properties that the human cognitive system monitors and encodes range from colour, texture, and shape to location and function. They can be classified based on specific distinctions. One of the most common classification systems was created by Jeannerod (1986), and differentiates extrinsic and intrinsic object properties. Extrinsic properties become relevant when performing actions with a certain object, while intrinsic properties are features that define the identity of the object. Similarly, Marno, Davelaar and Csibra (2013) have differentiated between transient and durable object properties. Transient properties may change in time (such as the location of an object), while durable properties are permanent and considered the core of the object's identity.

The distinctions between "extrinsic" and "intrinsic" (Jeannerod, 1986) or "durable" and "transient" (Marno et al., 2013) object properties resonate well with the neurophysiological dissociation found in visual object processing. There are two distinct neural pathways which contribute to the visual perception of objects: the dorsal route and the ventral route. While the former processes information relevant to guiding object-directed actions, such as location, size or motion, the latter

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plays a crucial role in processing information necessary for the identification of objects (Goodale, Milner, Jakobson & Carey, 1991; Milner, & Goodale, 1995; Ungerlieder & Mishkin, 1982).

Under normal circumstances, different properties become integrated into complex representations of objects, however, in certain cases, the distinct processes and their ontogenetic trajectories can be manifested. Based on extensive research with infants, investigators have concluded that location has primacy over surface features when infants process information about objects (Káldy & Leslie, 2003; Kellman and Spelke, 1983; Newcombe, Huttenlocher, & Learmonth, 1999; Xu & Carey, 1996). For example, infants use spatiotemporal information to individuate objects at 10 months of age, but they cannot do the same based solely on feature information (Xu & Carey, 1996). Since the seminal paper of Xu and Carey (1996), it has been shown that, under distinct circumstances, even young infants can take featural properties of objects into account (e.g. Wilcox & Baillargeon, 1998). Nonetheless, the claim that accurate processing of spatiotemporal information precedes that of surface features remains widely accepted.

Mareschal and Johnson (2003) suggest that although the infant brain is prepared to process both types of information, it takes longer for an adult-like representation of the object to be achieved by integrating information processed independently by the ventral and dorsal pathways described above. Mareschal and Johnson (2003) also found that location information is not always favoured over feature information, but that a feature-based representation can be induced by applying stimuli appropriate for the ventral stream. In their study, 4-month-old infants spent more time looking at scenarios violating expectations of location when the target stimuli were toy figures (and thus could be manipulated), but responded to violation of expectations of featural information when they were presented with human faces or two-dimensional asterisks (Mareschal & Johnson, 2003). Similarly, Kaufman, Mareschal and Johnson (2003) suggest that the graspability of an object determines which aspect of the object is more likely to be processed and maintained. Thus, we have reason to believe that an infant's tendency to process location and ignore surface features is not due to the inability to process feature information per se, but rather to the difficulty of integrating the two types of information, as well as the fact that the characteristics of the target objects used in most studies induce an action-relevant attitude.

A study by Haun, Call, Janzen and Levinson (2006) took a different approach to the problem: it investigated spatial memory and strategy-making in an object-locating paradigm with 1- and 3-year-old humans and apes. During the demonstration, a reward (a piece of food or a toy object) was hidden under one of three containers, each with a distinctive shape and colour. Then, two of the containers were switched out of the subject's sight in a way that the reward either moved with the container or remained in its original place. In the test phase, participants had to choose between the containers and were rewarded if they were correct. The task was particularly puzzling because participants only had access to ambiguous information about the location of the reward, which could either move with the container or stay at its original location. Importantly, therefore, a successful search strategy cannot be objectively defined. In this ambiguous object-search task, 3 year-olds showed a clearly different search strategy as compared to preverbal infants and adult apes. Namely, one-year-olds and apes tended to use a location-based strategy, as they found the reward more often when it was left in its original location, whereas 3-year-olds preferred to rely on a feature-based strategy and performed better if the reward moved with the container. This study suggests a shift from devoting more attention to an object's location (transient property) to focusing on its features (durable properties) between the ages of 1 and 3.

However, this shift may not only be achieved due to maturation. The Natural Pedagogy theory put forth by Csibra and Gergely (2006, 2009) claims that communicating knowledge about different objects or artefacts highlights their durable properties. According to the theory, ostensive-referential signals induce a genericity bias, which leads the audience of the communication to assume that the presented knowledge is not only valid in the given context but can successfully be applied to various situations. Thus, the information is likely to refer to a kind, rather than just a particular object. This has been confirmed in a study where 9-month old infants were shown to retain information about the location of an object in a non-communicative situation; however, memory was better for the identity of the object in a communicative context (Yoon, Johnson & Csibra, 2008).

Marno et al. (2013) investigated the effect of a communicative context on object-related memory in adults. Similar to previous findings, they demonstrated that communicative presentation of the stimuli improved memory for object identity at the expense of encoding information about its location. Interestingly, adults' performance was somewhat better for location when no cues were presented.

Based on the aforementioned findings, we aimed to directly compare the effects of communication on children and adults' object-directed behaviour in this study. The theory of natural pedagogy (Csibra & Gergely, 2009) proposes that ostensive-referential cues direct children's attention to the durable properties of objects and evoke an expectation in the recipient that they will be presented with generic information. This hypothesis has already been confirmed in studies with infants and adults (e.g. Yoon et al., 2008; Marno et al., 2013). Here, we applied a paradigm similar to the one that Haun et al. (2006) developed to investigate participants' strategizing in an object hiding and finding task. In order to gain a better understanding of participants' behaviour, we manipulated the context of the demonstration so that half of the participants saw a highly communicative hiding action while the other half witnessed a non-communicative demonstration. Haun et al.'s (2006) results suggest that neither the 1-year-old, nor the 3-year-old participants, had a perfect understanding of the ambiguous nature of the task since a full appreciation of the characteristics of the situation – that the reward could either move with the container or not – would lead participants to choose randomly. Therefore, we included a sample of adult participants in our study to test whether preference for a feature based strategy was characteristic of a mature cognitive system that potentially serves evolutionary adaptive functions (see Haun et al., 2006) or reflects a bias that stems from an imperfect comprehension of the situation. In the former case, adults would choose based on featural information, whereas in the latter case, they would not opt for any specific strategy. It is also plausible to assume that their behaviour will not be moderated by the presence of ostensive-communicative cues as previous results suggest that such signals most likely affect the level of encoding (e.g. Yoon et al., 2008; Marno et al., 2013). In the case of adults, we have no reason to assume that encoding different aspects of the demonstration would pose any serious demands on their cognitive system. Therefore, the presence of communicative cues may not modify their behaviour.

However, infants' choices may be more easily influenced by the attention-grabbing properties of the hiding event (i.e. presence or absence of communicative cues) as infants, most likely, have difficulty in simultaneous encoding of different aspects of the situation. Moreover, since the task involves invisible displacement, infants have to be able to keep track of the different objects even when they cannot see them for a while. Evidence suggests that it is not until the age of 12 months that infants start to bind featural information to spatiotemporal information (Xu & Carey, 1996). Hence, at the end of the first year of life, infants' representations of objects may still be fragile. In this case, ostensive cues could signal to children how to allocate their attention and which aspects of the demonstration would be significant. We therefore hypothesized that, in a non-communicative context, infants would choose based on the last seen location of the reward, but that this would shift towards a feature-based search strategy in the communicative situation.

2. Method

2.1. Participants

Children: Thirty-four 13.5-month-old (mean age: 13.71 months; range: 11.86–14.53 months) infants participated in the study. In addition, nine infants were tested, but later excluded from the final sample due to passivity ($N = 6$), inappropriate demonstration ($N = 2$) or because the parent did not cooperate with the instructions ($N = 1$).

Adults: Forty adults (mean age: 24 years; range: 19.6–36 years) also participated in the experiment. One additional adult was tested, but later excluded from the final sample due to inappropriate demonstration.

Subjects were randomly assigned to one of the two experimental conditions (ostensive-communicative or non-communicative – see below) so that the distribution of age and gender did not differ across conditions in each age group (Table 1). Adult participants and the parents of all infants gave informed consent. Ethical approval was obtained from the National Psychological Research Ethics Committee (Ref. No. 2011/13).

Table 1
The distribution of subjects in the conditions and age-groups.

	13-month old infants (males/females)	Adults (males/females)
Ostensive-Communicative demonstration	10/6	5/15
Non-communicative demonstration	9/9	5/15
Total	*19/15*	*10/30*

2.2. Setup and materials

Infants were tested in the laboratory (4 m × 4 m) of the Institute of Cognitive Neuroscience and Psychology, Hungarian Academy of Sciences, whilst adults were tested in a room (5 m × 2.5 m) of the Department of Ethology, Loránd Eötvös University. The same experimental setup was used at both locations. The setup was placed in one corner of the experimental room and was hidden by a curtain in order to prevent subjects from seeing it upon entering.

The apparatus consisted of two bell-shaped opaque plastic containers (10 cm high with an 8 cm radius) placed about 60 cm apart from each other, turned upside down. The two containers differed in colour (white and brown), but were otherwise identical. A tennis ball was used as a target object (reward) for all subject groups, which was placed on the ground between the containers at the beginning of the demonstration phase (Fig. 1).

2.3. Procedure

When testing infants, the parents were asked to sit on a blanket on the floor placed at a distance of 3 m from the apparatus, facing it, and hold their infants on their laps. Adults were seated on a pre-positioned chair, the same distance from the apparatus as stated for infants. The procedure consisted of a demonstration phase followed by a test phase. The type of demonstration depended on experimental condition (Ostensive-communicative vs. Non-communicative), while the test phase was identical for every participant. The tests with infants were carried out by a female experimenter (K.K.), while those for adults were performed by a male experimenter (A.CS).

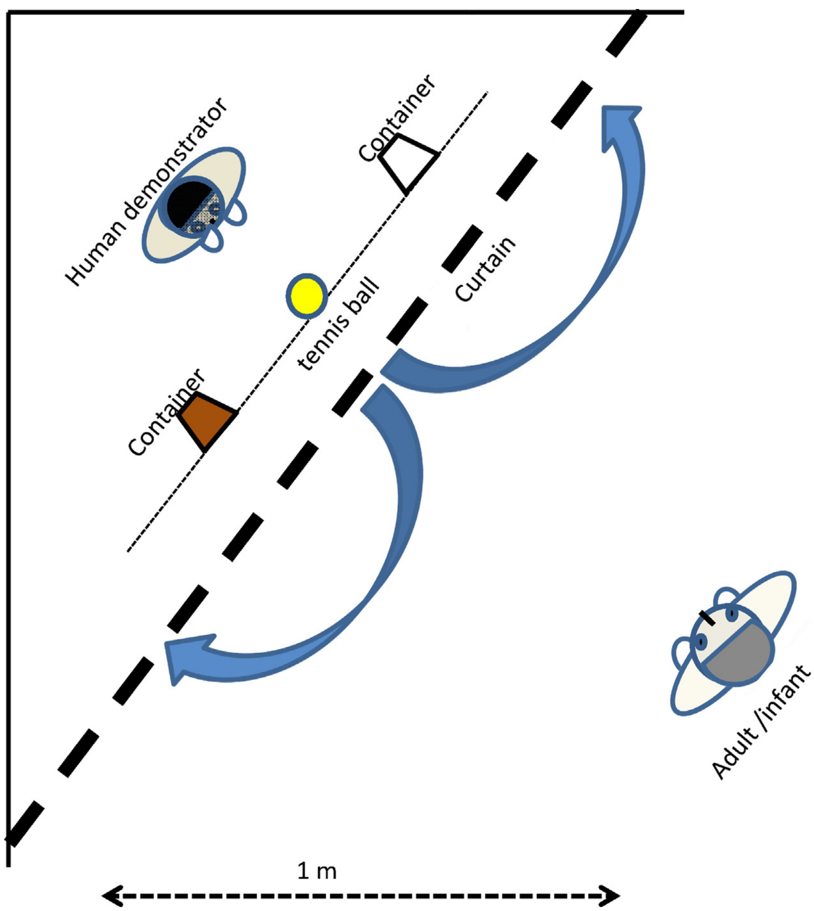

Fig. 1. Experimental arrangement.

2.3.1. Demonstration phase

Ostensive-communicative (OC) condition: After seating the participant, the experimenter went behind the closed curtains, stood behind the two containers (in the middle), and then pulled the curtains open. She/he started the demonstration by making eye-contact with the subject and then touched the top of both containers simultaneously (in order to avoid local enhancement). After this, the experimenter called the subject's attention by calling their name and saying: "Look! I will show you something interesting!" She/he then dropped the tennis ball onto the ground two times. Then the experimenter called the subject's attention again by making eye contact and saying "Look!" and put the tennis ball under one of the containers. After this, she/he pulled the curtains back closed. Behind the curtains, the experimenter took the ball from under the container, then pulled the curtain open again and repeated the whole procedure two more times. In all three cases, she/he placed the ball under the same container.

Non-communicative (NC) condition: The demonstration in this condition was identical to the one in the OC condition, except that communication was entirely eliminated. Thus, the experimenter made no eye contact with the subject, but rather turned her/his face towards the ground for the duration of the demonstration. Furthermore, she/he did not talk to the subjects, but mumbled a short unmeaning poem in the same part of the demonstration where verbal communication was used in the OC condition. This was necessary in order to control for the possibility that subjects are simply more attentive in the presence of verbal cues. Except for these changes, the demonstration procedures mimicked those in the OC condition.

The colour and the position (left/right) of the target container were counterbalanced across conditions.

2.3.2. Test phase

The demonstration phase was immediately followed by the test phase. The experimenter changed the location of the two containers (and thus the location of the target object as well) while the curtains were closed and then opened them. She/he then left the apparatus and stood to the side, while saying: "It's your turn now! Where is the ball?" For the infant participants, parents were allowed to encourage their child to go and look for the ball, but they were not allowed to point at the containers or to focus the infant's attention to a particular spot in any way. If adult subjects made inquiries about the purpose of the task or asked what they were supposed to do, the experimenter repeated the instructions but said nothing more. All subjects had 90 s for free exploration.

After the test phase, adult participants were asked to fill out a questionnaire in which they were explicitly asked what they thought the purpose of the task was. Participants could choose between the following four possible answers: (a) to find the ball (b) to copy the demonstrator's behaviour (c) something else (d) I don't know.

2.4. Coding and data analyses

For the analyses, we coded subjects' first choices between the two containers. A type of behaviour was regarded as a choice if the subject touched either of the containers. However, in one case, where the child proved to be too shy to approach the setup and make physical contact with the containers, we accepted a clear pointing gesture towards a container as a choice (infant group: $n = 1$). Furthermore, to test whether subjects were motivated and regarded finding the tennis ball as the aim of the task, we coded whether subjects obtained the tennis ball and whether the retrieval terminated the manipulation of the containers.

In order to assess inter-observer agreement with respect to infants and adults' choice behaviour, a second person, who was blind to experimental conditions, scored a sample from each age group (infants: 76%; adults: 100%). Cohen's Kappa values showed a high level of reliability in all subject groups (infants: Kappa = 0.946; adults: Kappa = 1) (Landis & Koch, 1977).

3. Results

The proportion of subjects selecting the empty or the baited container was analyzed by Generalized Linear Model (SPSS 17) and Binomial tests for binary data. GLM was used to test the effects of age group (adult vs. infant), Condition (Ostensive-communicative vs. Non-communicative), and Sex (male vs. female) on subjects' object-search strategy (location-based vs. feature-based).

Age group had a significant main effect on the strategy the participants chose to search for the ball ($\chi^2_{(1)} = 4.29$; $p = 0.038$), showing that infants were more likely to employ a location-based strategy (21 out of 34 participants) than adults (15 out of 40) (Fig. 2). However, using binomial tests, we found no clear preference for strategy either in case of adults ($p = 0.154$) or infants ($p = 0.175$). Moreover, the GLM analysis yielded no main effects of Condition ($\chi^2_{(1)} = 0.854$; $p = 0.355$) or Sex ($\chi^2_{(1)} = 0.7$; $p = 0.448$) and we could not find any significant interactions between Condition, Age group and Sex ($p > 0.1$ in each case).

Furthermore, to test whether infants understood that the purpose of the task was to find the ball and whether they were motivated to look for it, we also analyzed whether infants continued searching until they managed to retrieve the ball and whether locating the ball terminated the manipulation of the containers. We found that the great majority of infants (88.2%) managed to obtain the tennis ball and even those who were unsuccessful ($N = 4$, all in NC condition) exhibited some interest in the setup by pointing to one of the containers or by touching one without lifting it. More importantly, success in retrieving the ball ended the manipulation of the containers in all cases.

To ensure that adults also regarded obtaining the tennis ball as the purpose of the study, we coded the same categories as we did for the infants. All but two adults continued searching after checking the empty container, and all of them stopped

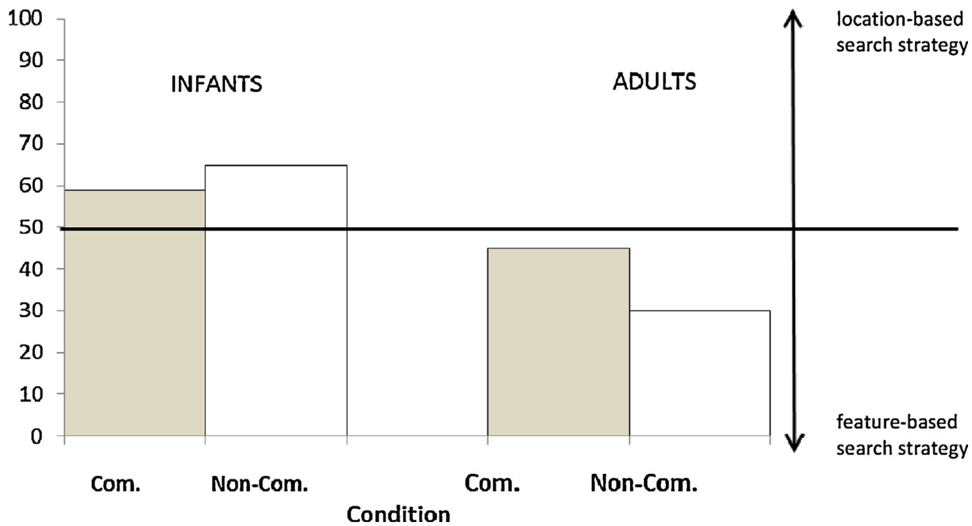

Fig. 2. Proportion of subjects employing a location based strategy. Proportion (%) of infants and adult human subjects employing a location-based object search strategy in the Communicative (Com) and the Non-communicative (Non-Com) conditions.

manipulating the containers after they managed to retrieve the ball. One subject went on to manipulate the empty container after a correct choice of the baited one but then did not notice the ball rolling out from under the container. Furthermore, while analysing the answers to the questionnaire, we found that the majority ($N = 33$) of adults chose "to find the ball" as an answer to the question, while four of them answered that the purpose was to copy the demonstrator's behaviour and three of them thought that it was something else (they assumed there was some trick in the task).

Finally, it is also worth mentioning that in the choice behaviour of the subjects, we found a marginal preference for the brown container by the infants ($p = 0.089$), and no container preference by the adults ($p = 0.268$). We found no side preference either in case of adults ($p = 0.875$) or infants ($p = 0.5$) (binomial tests, test proportion: 0.5).

4. Discussion

In this study, we tested whether infants and adults focus on different properties of an object in a toy-hiding paradigm depending on the context of the hiding event (ostensive-communicative vs. non-communicative). While most studies that explore the effects of the demonstration usually target the level of encoding, we investigated how it affects behaviour regulation in an ambiguous situation. Our study aimed at extending the results of Haun et al. (2006) and exploring how different biases in object-directed behaviour develop. We hypothesized that the behaviour of adults and infants would be influenced by potentially different processes. We expected adults to either choose based on the features of the objects or show a random search strategy. We also proposed that an infant's searching behaviour would be modulated by biasing the encoding of the scenario in the demonstration phase.

We have found partial support for our hypotheses. First, our results show that infants and adults indeed adopt different strategies when confronted with an ambiguous hiding event. Namely adults – as compared to infants – tended to rely more on feature information and followed the switch event in order to find the ball. These results correspond to Haun et al. (2006), who showed a developmental shift in search strategy between the ages of one and three. However, a closer examination of the results shows that this shift does not mean that adults develop a clear preference for a feature-based strategy. In their case, appreciating the ambiguity of the task could have resulted in a conscious choice of random searching strategy irrespective of the context of the demonstration. Infants, on the other hand, may have had more difficulty in memorizing every aspect of the situation and possibly could not fully understand the ambiguity they were faced with. Their choice, therefore, could have merely reflected a tendency to orient towards the last seen location rather than a conscious choice to randomly select a container.

Contrary to our expectations, the context of the hiding event did not matter either for adults or infants. When faced with an ambiguous situation, participants did not adjust their behaviour according to the context of the demonstration, showing that communicative cues did not prompt focus on the featural properties of the object in question, even in the case of infants. Nevertheless, we cannot conclude that communication did not affect participants' information processing at all.

Our experiment was designed in a way that participants were 'forced' to rely either on location or on feature information to search for the ball. Therefore, responses did not only reflect how the context of the demonstration affected encoding. As a consequence, the present study cannot fully disentangle the levels of encoding and behaviour execution. Participants' performance may have remained unaffected by the context either because the demonstration failed to elicit differential encoding of information or because participants did not take the communicative nature of the demonstration into account when planning their behaviour. Previous results have repeatedly shown that a communicative context qualitatively changes the encoding of a scenario even in case of infants. For example, Yoon et al. (2008) have demonstrated a memory bias in learning about the features or the location of an object; whereas Futó, Téglás, Csibra and Gergely (2010) have shown that presenting object functions in a communicative manner induce kind-based learning. Considering these findings, we propose that our results can be best explained by the inability to inhibit a prepotent answer to orient towards the last seen location of the object rather than by "immunity" to ostensive cues. Note that most of the studies that have proven the existence of the genericity bias in infants (e.g. Yoon et al., 2008) have used looking-time paradigms.

However, the interpretation described above is still plausible considering the results of Topál, Gergely, Miklósi, Erdőhegyi and Csibra (2008) with the A-not-B error. Their study has shown that although a non-communicative demonstration reduces infants' tendency to repeatedly (and erroneously) search for a toy in its original hiding location, it is not fully eliminated by changing the context. Since in the Topál et al. study the containers had no distinctive features, infants may have used location as the basis of generalization (e.g. "the toy belongs in container A"). Note, however, that our study involved two containers with different featural properties, which could have considerably increased the complexity and difficulty of the task for infants. It is also worth mentioning that the standard A-not-B task used in the above-mentioned study does not involve occlusion; the change of location happens in full view of the infant, whereas in our study, participants did not see the relocation of the object. Therefore, participants could have been more easily confused, leading to a lack of context effect.

Finally, comparing our results with that of Haun et al. (2006) could shed some light on the processes that influence the behaviour of different participant groups. Haun et al. have shown that 1-year-old children choose based on the location of the container, which is consistent with our own results. They have also found that – in contrast – 3-year-old children prefer a feature-based strategy. While the procedures for our study differed from that of Haun et al. (e.g. only one trial per participant; but with three repetitions of the demonstration; using two containers instead of three, with different colours but identical shapes), the most notable difference between the two paradigms concerns the context of the demonstration. While we systematically manipulated whether the demonstration was accompanied by communication or not, Haun et al. (2006)

conducted their experiments in the standard fashion: communicating with the children in order to increase the involvement of the participants. Therefore, their findings can be best compared with our results in the Ostensive-Communicative condition, confirming our claim that despite infants' sensitivity to ostensive-communicative cues, the effect of communication is not exhibited in active paradigms due to the immaturity of other processes (such as inhibition). We propose that 3-year-old children chose a feature-based strategy in Haun et al.'s study because their cognitive processes were mature enough for communication to effectively influence not only their encoding of the situation but – through that – their execution of behaviour as well. Our results with adults complement the interpretation by showing that such biases are fully eliminated when a perfect appreciation of the ambiguity of the task is acquired.

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