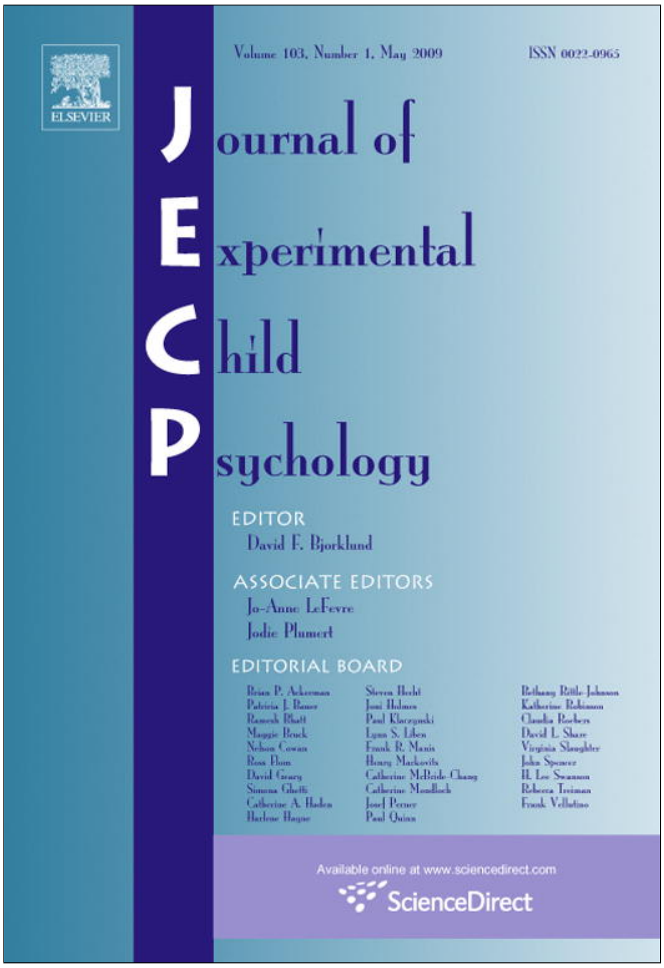
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Brief Report

The development and robustness of young children's understanding of aspectuality

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ABSTRACT

We investigated whether 6-year-olds' understanding of perceptual aspectuality was sufficiently robust to deal with the presence of irrelevant information. A total of 32 children chose whether to look or feel to locate a specific object (identifiable by sight or touch) from four objects that were hidden. In half of the trials, the objects were different on only one modality (e.g., four objects that felt different but were the same color). In the remainder of the trials, the objects also differed (partially) on one irrelevant modality (e.g., four objects that felt different, two red and two blue, where the goal was to locate the soft object). Performance was worse on the latter trials. We discuss children's difficulty in dealing with irrelevant information.

Introduction

As adults, we know what type of perceptual action we need to take to learn specific information. We understand that evidence from these actions will support our knowledge (e.g., that we should look if we want to find out the color of something) and that particular actions deliver information to different modalities, providing specific types of knowledge (e.g., Dretske, 1969). This is known as aspectuality (Perner, 1991). Comprehension of aspectuality is central to the development of metacognitive abilities during childhood. For example, this understanding indicates an appreciation that underlying mental processes can be related to knowledge and behavior, an ability that is crucial to the development of theory of mind during middle childhood (between 7 and 12 years of age) (Astington, 1993; Wellman, 1990). Although many experiments have investigated the development of young children's comprehension of aspectuality and its relationship to theory of mind (e.g., O'Neill, Astington, & Flavell, 1992; Pillow, 1993; Robinson, Thomas, Parton, & Nye, 1997), there has been limited research into the

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robustness of aspectuality understanding in its own right. The current study aimed to establish whether 6-year-olds possess a robust, adult-like comprehension of aspectuality.

In tasks assessing understanding of aspectuality, children tend to be presented with two (or more) objects that share one perceptual modality but differ in another. For example, the objects might either look the same and feel different or feel the same and look different. One or more of these objects is then hidden, and children are asked to choose between looking and feeling as the appropriate source of knowledge. Their ability to choose the correct mode of perceptual access to identify or locate the hidden target reflects their understanding of the link between perception and knowledge. Chandler and Boyes (1982) proposed that prior to having this understanding, children behave as though perceptual information is simply transmitted or copied into the mind rather than being actively processed and interpreted. Once one has a grasp of aspectuality, knowledge is understood to be obtained more selectively; feeling something will not tell one about its color.

One suggestion regarding the development of aspectuality is that children progress through three stages of understanding that culminate in a mature comprehension (O'Neill et al., 1992). During the initial stage, at around 3 years of age, children understand that perceptual access to a hidden object will lead to knowledge about that object and that a lack of perceptual access will not lead to knowledge, for example, that a puppet looking at a toy inside a tunnel will know its color but a puppet resting his hand on the outside of the tunnel will not (O'Neill et al., 1992). However, children of this age behave as if any one type of perceptual access will provide all of the information they need (e.g., Robinson et al., 1997; Taylor, 1988).

During the second stage, 4- and 5-year-olds are able to reflect on, and state, what specific perceptual action led to the acquisition of a piece of knowledge (e.g., Gopnik & Graf, 1988; O'Neill & Gopnik, 1991). They can demonstrate their understanding of the causal link between perception and knowledge (e.g., Wimmer, Hogrefe, & Perner, 1988). For example, children who are asked to justify a puppet's lack of visual knowledge point out that the removal of a blindfold would have let the puppet know the object's color (O'Neill et al., 1992). However, it is only at the third stage of understanding, at around 5 or 6 years of age, that children develop the ability to choose correctly which perceptual action is necessary to obtain knowledge. In other words, it is only at this age that children are able to understand how to use visual and tactile perceptual access to gain knowledge in an adult-like way (O'Neill et al., 1992).

A mature understanding of aspectuality, as defined by O'Neill and colleagues (1992), requires comprehension of how an object is made up of many separate features, each of which can be identified by different perceptual actions. So, one would expect that someone with a mature understanding of aspectuality would be able to ignore information regarding irrelevant perceptual features. When someone is skilled in a task, the presence of irrelevant information offers no distraction (e.g., Haider & Frensch, 1999). For example, imagine several cans of soda on a table. If told to find out which one was half-full, an adult (with a mature understanding of aspectuality) would pick up each can of soda in turn rather than examine the different labels on the cans. Visual information from the outside of the opaque cans would be irrelevant in this situation. Similarly, if told to identify a can of a particular brand of soda, a mature thinker about aspectuality would visually examine each can rather than base his or her decision on how each can felt. One way to examine the robustness of young children's understanding of aspectuality is to include irrelevant information in the task.

Young children can show quite advanced understanding of how to deal with irrelevant information. For example, 3-year-olds are able to select information that is relevant and ignore information that is irrelevant in visual search tasks (Sophian & Wellman, 1980). However, young children's understanding of aspectuality has never, to our knowledge, been tested in terms of whether these children can identify relevant and irrelevant information. If 6-year-olds possess an adult-like understanding of aspectuality, as suggested by O'Neill and colleagues (1992), then they should be able to deal with situations where an aspectuality task contains additional but irrelevant information. However, a more fledgling understanding may be upset by the introduction of irrelevant information.

In the current research, we tested the robustness of children's understanding of aspectuality by introducing irrelevant information to the array of objects used in the task. This irrelevant information concerned the different and shared features of the objects. We were interested in children's ability to recognize the features that were relevant to the task and those that were irrelevant. We did this by adapting an aspectuality task where one modality (e.g., color) would offer some differentiation between the objects but not enough to distinguish between them completely. In this way, the partial differentiation was irrelevant and should be recognized as not assisting in the location of the hidden target.

Method

Participants

A total of 32 6-year-olds from a school that served a predominantly working class population in Birmingham, United Kingdom, were tested. Their ages ranged from 5 years 10 months to 6 years 9 months (mean = 6 years 4 months, 9 girls and 23 boys [the smaller proportion of female participants was representative of the school's intake that year]). The ethnicity of the children was distributed as follows: White (26), Asian (2), Black (2), and other (2). All of the children were reported by their class teachers as possessing a good understanding of English.

Materials

The materials consisted of 17 balls, four tunnels, an opaque bag, and an opaque cloth. The balls were approximately 7 cm in diameter and were in five different colors with five different fillings. Balls of the same color but different "feels" were indistinguishable by sight. The ball used for the familiarization procedure was orange and was filled with a hollow cardboard sphere so that it felt hard when squeezed. The other balls were used for testing and were red, blue, green, and purple (four of each color). One of each of these colors contained one of the following fillings: soft foam (referred to as *soft*), a thin soft foam outer layer with a wooden cotton reel inside (*knobbly*), a thin soft foam outer layer filled with polystyrene beads (*bobbly*), or a thin soft foam outer layer with a center of solid plaster (*heavy*). All of the balls were kept out of sight in the opaque bag when not in use.

Four square gray tunnels, measuring approximately 30 × 10 × 10 cm, were used as hiding places for the balls (see Fig. 1). The tunnels were identical, with 5-cm-diameter holes cut in their 10 × 10-cm ends and "hook and loop" patches that allowed the tunnels to be securely stacked on top of each other. On one end of each tunnel, the holes were covered with clear plastic, forming windows that could be looked through to see inside. On the other end of each tunnel, the holes were covered by pieces of black felt with two diagonal slits cut into them so that a child's hand could pass through. Black felt squares were attached at the top of the outside of the ends of the tunnels so that the win-

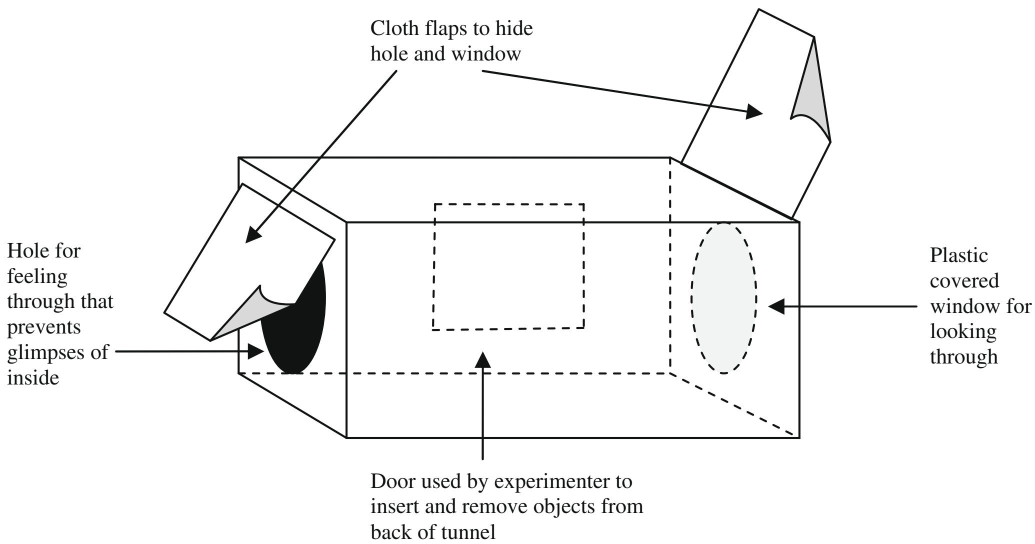

Fig. 1. Example of a tunnel used to hide the balls.

dows and feeling holes were covered with flaps of felt that needed to be lifted up for someone to look in or put a hand in. Each tunnel also had a door on the back panel that could be opened by the experimenter and through which the balls were inserted and removed. The opaque cloth was used to hide the movements of the balls, both their positioning in the tunnels and their transfer from the opaque bag.

Design

We adapted an aspectuality task used by Pillow (1993) where children were presented with three objects that shared one perceptual property but differed in another. In Pillow's study, all of the objects were hidden, one in each of three containers, and children were asked what perceptual access was needed to find one of the objects (e.g., the blue one). Using this procedure with four balls allowed us to include irrelevant information in the array of objects.

In our task, each child received eight test trials. Four contained a partially differentiating (PD) secondary modality (e.g., four balls that felt different but were different colors [two were red and two were blue]), and four contained a nondifferentiating (ND) secondary modality (e.g., four balls that felt different but were all the same color). Each child received four trials where the target was identified by color ($2 \times$ PD and $2 \times$ ND) and four trials where the target was identified by tactile quality ($2 \times$ PD and $2 \times$ ND). The "looking" and "feeling" trials were arranged to give four fixed orders of presentation: Feel/Look/Feel/Look/Feel/Look/Feel/Look (FLFLFLFL), LFLFLFLF, FLLFLFFL, and LFFLFLLF. Children were assigned in turn from the teacher's class list to one of the four trial presentation orders. The order of PD and ND trials, the appearance of the target, the target identity, and the location of the target in the array of tunnels were counterbalanced across children to prevent any order effects. The question order was alternated so that half of the children were asked whether they wanted to look or feel to find the target and the other half were asked whether they wanted to feel or look.

Procedure

Familiarization

Children were tested individually in a quiet room. They were told that they were going to play a game. The bag of balls and a tunnel were placed on a table in front of the children. The experimenter took the orange hard ball from the bag and placed it inside the tunnel through the back door (under the cloth so that the children could not see). The experimenter then pointed to the appropriate end of the tunnel and explained that there was a window underneath the flap. Children were asked to look inside and say the color of the ball. Following their responses, the children were told, "That's right, it's orange, and you could tell it was orange because you looked at it, didn't you?" Children were then informed, "I'm taking this ball out now and putting another ball in" (to demonstrate that the balls were not left in the tunnel), although in fact the same ball was reinserted. The experimenter then pointed to the other end of the tunnel and explained that on this end of the tunnel there was a hole underneath the flap. Children were asked to feel inside the tunnel and say what the ball felt like. Following their responses, the children were told, "That's right, it's hard, and you could tell it was hard because you felt it, didn't you?"

The other tunnels were then brought out and stacked underneath the original one. The tunnels formed a tower so that all of the windows were on one end and all of the feeling holes were on the other end. Children were told that in the following game four balls would be hidden, one in each tunnel. Children were told that they would be asked to find one of the balls and would need to decide whether they wanted to look or feel to find it. As a check of the children's understanding of the difference between the two modes of access, the children were asked which side of the tunnels they would go to if they wanted to look and which side they would go to if they wanted to feel.

Test trials

Children received eight test trials. Before every trial, they were presented with the balls that were going to be used in that trial and were asked to make sure that they looked at them and felt them, and the experimenter described the perceptual attributes of each ball in turn (e.g., "This one is red and heavy"). The descriptions were carried out in a predetermined and counterbalanced order for each trial. The modality that distinguished the target was always mentioned first. For example, if the target was red, then the colors of the balls were described first. The balls were then hidden in the tunnels in a predetermined order so that the target ball's position varied in the tower. This took place underneath the cloth so that the children could not see. Children were then asked to find the target (e.g., "Find the red one" followed by "What do you want to do to find the red one? Would you like to look or would you like to feel?").

Children's responses were noted, and they carried out their chosen action. They were then asked to indicate to the experimenter which tunnel they thought contained the target ball. They were not permitted to carry out the alternative action. Children were handed the ball from their chosen tunnel, but no correction or feedback was offered by the experimenter. The balls were removed from the tunnels before the next trial was started. At the end of the game, every child was rewarded with a sticker.

Results

Scoring

All children passed the understanding check in the familiarization task (knowing which sides of the tunnel allowed seeing and feeling) and so took part in the experimental trials. We calculated the proportion of trials on which children chose the appropriate action; thus, the children's scores on looking and feeling trials range from 0 to 1 (see Table 1).

Data analysis

Proportions of correct answers for looking and feeling trials were entered into a repeated measures analysis of variance (ANOVA) with type of irrelevant information (PD vs. ND) and modality (looking vs. feeling) as within-participant factors. The results showed a main effect of information type, $F(1,31) = 8.75$, $p = .006$, $\eta^2_p = .22$. Children performed better on the ND trials ($M = .76$) than on the PD trials ($M = .62$). There was no effect of modality, nor were there any interactions. One-sample t tests were used to compare performance with that expected by chance (0.50). On ND trials, children performed better than would be expected by chance on looking trials ($M = .83$, $SD = .30$), $t(31) = 6.17$, $p < .001$, $r = .74$, and on feeling trials ($M = .69$, $SD = .38$), $t(31) = 2.82$, $p = .008$, $r = .20$. On PD trials, children performed marginally better than would be expected by chance on looking trials ($M = .66$, $SD = .41$), $t(31) = 2.15$, $p = .039$, $r = .36$, but not on feeling trials ($M = .58$, $SD = .38$), $t(31) = 1.15$, $p = .26$, $r = .20$.

Discussion

Children were more successful at choosing the correct perceptual access to find a target when they had an array of objects offering no secondary modality differentiation than when the array included a partially differentiating secondary modality. Children did not treat the partially differentiating infor-

Table 1
Proportions of trials correct.

Trial type/modality ($N = 32$)	Proportion of trials correct and standard deviation
Partial differentiation/looking	.66 (.41)*
Partial differentiation/feeling	.58 (.38) *ns*
No differentiation/looking	.83 (.30)***
No differentiation/feeling	.69 (.38)**

Note. Standard deviations are in parentheses. *ns*, nonsignificant difference.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

mation in the array of objects as irrelevant information. They appeared not to realize that it was irrelevant to their decision as to what perceptual action to take to find, for example, the red object. Because the partially differentiating information was only apparent to the children in the array of objects before they were hidden, this pretrial experience of the objects must have affected their performance.

We considered whether the order in which we described the objects in the test trials could have influenced children's performance; we always mentioned the relevant modality first. In the existing literature, the experimenter often describes the way the objects differ before describing the way the objects are similar, keeping this consistent across all trials (e.g., Pillow, 1993; Robinson et al., 1997). However, mentioning the relevant modality first can result in unusual sentence constructions. For example, in English we typically use color descriptions after other physical attributes; we would say "the big red bus," not "the red big bus." Therefore, in the looking trials, we may have inadvertently informed children which modality they should attend to, whereas the descriptions in the feeling trials would have produced a more typical sentence structure and not have attracted the same attention. Yet if this were the case, then one would expect to find preferences toward looking or inflated performance levels, and we found neither. Furthermore, there is no reason to believe that this confound impacted any differently on the partially differentiating trials and on the nondifferentiating trials (which were the main focus of this experiment). In future work, however, this phrasing should be better controlled.

How does our finding fit with the stages of understanding aspectuality discussed in the Introduction? O'Neill and colleagues (1992) suggested that 5- and 6-year-olds are in the third and final stage of understanding aspectuality, which is comparable to that of adults (at least so far as looking and feeling are concerned). Our result shows that even 6-year-olds cannot be said to have such an understanding given that they were unable to deal with irrelevant information in the array of objects. O'Neill and colleagues (1992) also suggested that the ability to make causal connections is a second-stage development in the understanding of aspectuality, appearing at around 4 or 5 years of age. In our study, children could have solved the task by making an association, for example, between finding an object that was red and looking to find a color. They could disregard their experience of the objects before they were hidden and focus on the target question (e.g., finding the red one). However, even the 6-year-olds tested in the current study failed to make such an inference.

Why might the pretrial experience of objects disrupt children's ability to choose the correct modality to find one of those objects? Two pieces of existing evidence suggest that young children might have difficulty in experiencing similarities and differences between objects, possibly based on their ability to hold information in mind. First, Piaget (1952) proposed that children can find it difficult to focus on more than one feature of a display, a tendency known as centration. For example, in the classic conservation task, children might focus on the changeable way a group of objects can be arranged rather than on the unchanging number of objects. When children are able to decenter, or focus on more than one feature, they are potentially able to recognize which feature is valid. An understanding of aspectuality requires the ability to focus on more than one feature of an object and to decide which is relevant, for example, to recognize that an object might be the same color as others but be different from them in the way it feels. Therefore, it might not be until children reach Piaget's concrete operational stage, at approximately 7 years of age, that they would have the ability to deal with irrelevant information in an aspectuality task.

Second, Perner and Ruffman (1995) suggested that one reason why children under 6 years of age find aspectuality tasks to be difficult is the experience they have of the objects before they are hidden. This is because children's increasingly advanced ability to remember an experienced event underpins their understanding of aspectuality; children try to remember their experience of the objects yet have difficulty in encoding this information. Their attempt to recall the event disrupts their subsequent choice of which perceptual action is needed to find a particular perceptual quality. Our finding shows that even 6-year-olds' performance on aspectuality tasks is disrupted by their pretrial experience of the objects if that experience contains irrelevant but partially differentiating information. We suggest that one of the features of a robust understanding of aspectuality may be the ability to hold in mind the relevant characteristics of objects. Therefore, when information is more complex, it is increasingly difficult to hold that information in mind. If children were attempting to remember the perceptual qualities of the balls, then the extra information in the partially differentiating trials could have overloaded short-term memory capacities.

In summary, our finding shows that the development of young children's understanding of aspectuality might not be as clear-cut as O'Neill and colleagues' (1992) stages suggest. Despite evidence demonstrating that very young children possess a logical understanding of what information is relevant and irrelevant (e.g., Sophian & Wellman, 1980), 6-year-olds' handling of aspectuality was remarkably affected by the inclusion of irrelevant information. We suggest that a robust understanding of aspectuality might not be apparent until after other aspects of theory of mind have developed during middle childhood (e.g., Wellman, 1990). Thus, our finding expands the existing literature on children's understanding of aspectuality, identifying one way in which 6-year-olds' comprehension is not adult-like. Further research is required, however, to fully assess the intricacies of young children's understanding of aspectuality and the development of a robust understanding. Additional investigations should also reveal more about how this development might relate to the acquisition of other related abilities during early to middle childhood.

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