

Preschool Children's Difficulty Understanding the Types of Information Obtained through the Five Senses

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Two studies explored 3- and 4-year-olds' ($N = 60$) understanding that the five senses can each lead to different types of knowledge. In Study 1, 40 children engaged in five scenarios in which they could only perform one sensory action to identify the property of an object (e.g., color, scent). After performing the action, children were asked *how* they found out the property and to *show* the experimenter how they had found it out. Using a Mr. Potato Head doll, children were also asked to indicate the sensory organ the doll would need to use to identify the property. In Study 2, 20 children presented with five Mr. Potato Head dolls, each sporting only one sensory organ (e.g., a nose), were asked which Mr. Potato Head could find out the property in question. The 3-year-olds performed significantly poorer than the 4-year-olds on all tasks, suggesting a marked transition in children's ability to recognize the origin of their modality-specific knowledge during the time period between 3 and 4 years of age.

INTRODUCTION

Through their senses people experience objects and events in a myriad of different ways that ultimately provide different types of information about these objects and events. For example, a child looking at a marshmallow for the first time will learn that it is white and about the size and shape of an ice cube. When feeling it, the child will find out that it is not heavy and dense, but rather light and spongy. Some of the marshmallow's properties, such as its shape will be accessible through more than one sense, but others will not. For example, only when the child tastes it will its extreme sweetness be apparent.

As adults, our understanding of the relation between perceptual experiences and knowledge of the world is explicit and accessible. We not only understand that evidence is a necessary accompaniment of knowledge, but also appreciate the *modality-specific nature of knowledge*—the fact that different types of sensory experiences (i.e., evidence) support different types of knowledge (Dretske, 1981; O'Neill, Astington, & Flavell, 1992). Our understanding of the latter has also been referred to as knowledge of *aspectuality* (Dretske, 1969; Perner, 1991).

When do children develop an understanding of the causal origins of beliefs and knowledge that encompasses both of these components, namely (1) an understanding that evidence is a necessary accompaniment of knowledge, and (2) an understanding that different sensory experiences can lead to different types of knowledge? Children's knowledge of the first component has been investigated by asking them to provide a reason for how they know something; that is, to identify the source of their knowledge (e.g.,

Gopnik & Graf, 1988; O'Neill & Gopnik, 1991; Perner & Ruffman, 1995; Pillow, 1989; Wimmer, Hogrefe, & Perner, 1988; Wimmer, Hogrefe, & Sodian, 1988; Woolley & Bruell, 1996). Typically in such tasks, children discover the contents of a box through a single sensory means of access, such as looking inside it, and are then asked how they found out this information. In some studies, this question has been asked in an open-ended fashion (e.g., Perner & Ruffman, 1995; Pillow, 1989; Wimmer, Hogrefe, & Perner, 1988) whereas in others, children have been given two or more forced-choice options (e.g., Gopnik & Graf, 1988; O'Neill & Gopnik, 1991; Woolley & Bruell, 1996). Despite differences in the format of the test questions, the findings have been similar: 3-year-olds are somewhat able to identify the source of their beliefs, but in many cases their performance is substantially poorer than that of 4- or 5-year-olds. It is a topic of debate whether 3-year-olds possess a general deficit with respect to identifying the source of their knowledge (cf. Woolley & Bruell, 1996), because their performance appears to be better with some sources (e.g., seeing) than with others (e.g., being told). In every previous study, however, 3-year-olds have, at times, demonstrated a striking inability to identify the source of their knowledge that is not observed among older children. Given that children are asked to identify the source of their knowledge immediately after they have carried out the relevant sensory action (i.e., with no delay), researchers such as O'Neill and Gopnik (1991, p. 396) have argued that their poor performance

should not be attributed to a "simple memory deficit," but rather to an inability to encode source information at the time of the sensory experience.

Children's understanding of the second component—that different types of knowledge can be gained from different sensory experiences—has also been the focus of a number of studies (O'Neill et al., 1992; Perner & Ruffman, 1995; Pillow, 1993; Robinson, Thomas, Parton, & Nye, 1997; Weinberger & Bushnell, 1994). For example, children are shown and experience two objects that feel different (e.g., one is wet and the other dry) but look the same (i.e., no visual cues exist as to the object's state of wetness or dryness). The children are then shown one puppet "feeling" the object and another puppet "looking at" the object and they are asked which puppet "knows" the object is wet (e.g., O'Neill et al., 1992, Studies 2 and 3; Pillow, 1993, Studies 1 and 4). Alternatively, this ability has been probed by asking children what sensory action should be carried out, by themselves or a puppet, to gain information about a particular property (e.g., O'Neill et al., 1992, Study 3; Perner & Ruffman, 1995; Pillow, 1993; Rummel, 1999; Robinson et al., 1997; Weinberger & Bushnell, 1994). The general consensus from these studies is clear: 3-year-olds, and a significant portion of 4-year-olds, have great difficulty appreciating what types of information can be gained from different sensory experiences and their performance hovers around chance level. At times, 3-year-olds also overestimate the knowledge to be gained from a sensory source (e.g., seeing in Robinson et al., 1997; feeling in O'Neill et al., 1992).

The studies reported here incorporated three methodological advances in an effort to better assess young children's understanding of aspectuality. First, in addition to asking children *how* they had come to know the property of an object (e.g., "How did you find out . . .?"), children were provided with two non-verbal routes to demonstrate their knowledge. In one case, children were asked to *show* the experimenter how they had found out the property of the object. In another task, a Mr. Potato Head doll with five detachable sensory parts (eyes, ears, mouth, nose, and hands) was provided to children so that they could respond to a question by choosing one of its parts. Second, the senses under investigation in previous studies have included largely seeing, feeling, and, less often, hearing. One study (Weinberger & Bushnell, 1994) also focused on taste and smell in 4-year-olds, but procedural difficulties made the results difficult to interpret. In the studies presented here, children's understanding with respect to all five senses was systematically tested and contrasted. Finally, in these studies, the methodologies of previous studies have been im-

proved by constructing and using only stimuli that permitted children to find out the property directly through one sensory source without the need to carry out any potentially confounding intermediate actions (e.g., lifting the object to see it).

STUDY 1

Method

Participants

Participants were twenty 3-year-old children ($M = 44.5$ months, $SD = 2.44$, $range = 39$ – 48 months, 10 girls and 10 boys) and twenty 4-year-old children ($M = 55.7$ months, $SD = 3.35$, $range = 50$ – 60 months, 8 girls and 12 boys) recruited from the laboratory preschool at the University of Waterloo, Ontario. The children were largely from White, middle-class families. One additional child was tested, but this data was not used due to equipment error.

Materials

For each of the five senses investigated (see, feel, hear, smell, taste), an object (and corresponding test scenario) was carefully constructed and designed to meet two criteria. First, the property of the object (e.g., its scent) could only be discovered through the use of one particular sensory means (e.g., smelling). That is, the object provided no other cues (e.g., color) that could have acted as clues or permitted an inference as to its particular property. Second, for no object did the children need to perform any intermediary action (e.g., lifting it up) to find out the property of the object.

The five scenarios were as follows. For the see trial, a red ball was placed inside a tall, narrow paper bag that prevented the children from touching the ball and required that they look into the bag to determine the color of the ball (choice: red or green). For the feel trial, a miniature plastic swimming pool containing icy cold water was used into which the children could place their fingers to determine the temperature of the water (choice: warm or cold). For the hear trial, a tape player attached to a pair of small speakers played classical music at a very low volume so that the children had to put their ears to the speaker to determine the sound (choice: music or a person talking). For the smell trial, a small, clear plastic bottle of colorless bath oil mixed with essence of strawberry was used. The children had to sniff near the small opening of the bottle to determine the scent (choice: lemon or strawberry). For the taste trial, a clear (disposable)

cup containing plain water was used, which the children had to drink from to determine the taste (choice: sugary or plain). A Mr. Potato Head doll with detachable eyes, nose, mouth, ears, and hands was also used. All the sensory parts of the doll had velcro on one side so that they could be stuck on and taken off the doll easily. A picture of Mr. Potato Head (actual size) with all five sensory parts attached was also used in the test trials.

Procedure

Introduction. Children were tested individually in a small lab room attached to the preschool. The child and the experimenter sat at a small table and the experimenter told the child: "Today, we are going to play some games. I will show you some toys and you follow what I do. Let's find out what the toys are."

Experimental task. The experimental task consisted of two games. During Game 1, children were asked how they had determined a specific property of an object, and to show the experimenter how they had determined it. During Game 2, they were asked, using a Mr. Potato Head doll, to pick the sensory organ that Mr. Potato Head would need to use to determine the property. All children received five experimental trials during each game—one trial for each of the five sensory modalities. The order of the five modalities was counterbalanced according to a Latin square design and its reverse to produce 10 orders in total. Each order was carried out with one child of each gender, if possible.

In Game 1, the instructions and test questions given to children on each sensory trial were as similar as possible. The smell trial will be described as an example. At the beginning of this trial, children were told, "Here is a bottle of bubble bath. It is either strawberry bubble bath or lemon bubble bath. Let's find out what kind of bubble bath it is. Do like this." The experimenter then modeled the appropriate sensory action, in this case leaning over to sniff the mouth of the bottle. The experimenter never named the sensory action being performed (i.e., smelling). After the children had imitated her action, the experimenter asked the control question: "Is it strawberry bubble bath or lemon bubble bath?" If children did not respond spontaneously, or responded with a stereotyped response (e.g., I don't know), the question and action were repeated one more time. The control question was asked to ensure that children had correctly perceived the property of the object on each trial.

Immediately after children had identified the property, they were given two test questions, referred to as the How and Show test questions. The How test

question was always posed first and took the general form, "How did you find out the [object] is [the type that it is]?" For the smell trial, therefore, children were asked, "How did you find out the bubble bath is strawberry bubble bath?" After children had responded to this question, they were asked the Show test question, which took the general form, "Show me how you found out the [object] is [the type that it is]. So, for the smell trial, children were asked, "Show me how you found out the bubble bath is strawberry bubble bath." Children were to respond by repeating the action they had imitated. This entire procedure was repeated for the remaining four modalities (see, feel, hear, taste) and their corresponding objects (red ball, cold swimming pool, tape playing music, plain water).

At the beginning of Game 2, children were told they would now play a game with Mr. Potato Head and were presented with a Mr. Potato Head doll sporting detachable ears, eyes, nose, mouth, and two hands. They were also shown a picture of Mr. Potato Head sporting all five sensory organs. The children were asked to name each of the five sensory parts (ears, eyes, nose, mouth, and hands), to detach each, and to place it on top of the corresponding part on the picture (e.g., the nose of the doll would be placed over the nose of the doll in the picture). After the children had finished, the experimenter said to the children: "I'm going to show you some toys. You show me what Mr. Potato Head needs to use (pointing to all five body parts now on the picture) to find out what the toys are." The five sensory parts remained on the picture throughout the rest of the game.

The identical five objects used in Game 1 were presented as the "toys" in Game 2 with Mr. Potato Head, in the same order as in Game 1. The instructions also followed the wording of those for Game 1 as closely as possible. On Game 2 trials, however, the children were not asked to imitate the relevant action (because they had just done so in Game 1), but rather were asked directly what Mr. Potato Head would need to use to find out what kind of object it was. For example, in the smell trial, children were told: "Here is a bottle of bubble bath. It is either strawberry bubble bath or lemon bubble bath. What will Mr. Potato Head need to use to find out if the bubble bath is strawberry bubble bath or lemon bubble bath?" This question constituted the Mr. Potato Head test question of Game 2. In response to this question, children were to pick the correct sensory body part from the picture, in this case the nose, by either pointing to it, picking it up, or picking it up and sticking the part on the Mr. Potato Head doll. Once the child had responded, the part was placed back on the picture and the procedure was repeated for the next sensory trial.

Scoring

Control question. All but 5 children responded correctly to all the control questions asked during the sensory trials. Of the 5 children, 3 refused to taste the water, 1 refused to smell the bubble bath, and 1 refused to listen to the tape player and smell the bubble bath. On these six trials, children were not asked the test questions.

How test question. Two procedures for scoring children's responses were used; one lenient and the other conservative. These two scoring procedures were adopted because many of the children responded to the test question with an action rather than a verbal response. For example, when asked the How question on the taste trial, 1 child responded by drinking from the cup again instead of providing a verbal response such as "I tasted it." Therefore, to give the children the greatest opportunity to reveal any understanding that they might have had of the source of their knowledge, these action responses were also included as correct responses (presuming the action was the correct one) according to the lenient scoring procedure. For the more conservative scoring procedure, however, children's responses were only scored as correct if they gave an appropriate verbal response (e.g., "I took a sip"), or if they gave both a verbal plus an action response to this question. Thus, with the conservative approach, responses were scored as incorrect if children only gave an action response (e.g., drank from the cup again). For both lenient and conservative scoring procedures, a score of 1 was given for each trial on which children gave a response that was correct as defined by each scoring procedure. Thus, children received a score from 0 to 5 under both the lenient and conservative scoring procedures for the How question.

Show test question. Lenient and conservative scoring procedures were also used with the Show test question. According to the conservative scoring method, children's responses were scored as correct if they performed the appropriate action (e.g., put an ear to the speaker in the hear trial), or if they responded verbally and performed the appropriate action. Responses were scored as incorrect, however, if children only gave a verbal response (e.g., "I heard it") and did not demonstrate the action they had carried out to determine the property. Under the lenient scoring procedure, children who provided only a relevant verbal response (without any accompanying demonstrative action) were also scored as correct. A score of 1 was given for each trial on which children gave a response that was correct as defined by each scoring procedure. Thus, children received a score from 0 to 5 under both the lenient and conservative scoring procedures for the Show question.

Occasionally, some 3-year-old children demonstrated the source of their knowledge in response to the How or Show question by directing the relevant sensory action toward the experimenter. For example, on a hear trial, 1 child put the speakers to the experimenter's ears. This type of action response was included among children's correct action responses because the action was specific to the sensory modality in question, demonstrating that the child understood what sense organ was required to find out the particular property of the object. If a child's action was not specific to the sensory modality in question, however, (e.g., in the smell condition, a 3-year-old child simply handed the experimenter the bottle of bubble bath), it was not included as a correct action response. Such incorrect, non-specific action responses only occurred in response to the Show question.

Mr. Potato Head test question. Children received a score of 1 if, in response to the Mr. Potato Head question, they chose the correct body part associated with the specific sensory modality in question. A score of 0 was given for choosing the wrong body part. Thus children received a score from 0 to 5 (i.e., a score of 1 or 0 on each of the five sensory trials) for the Mr. Potato Head question.

Results

A three-way repeated-measures ANOVA was conducted separately for children's scores on each of the test questions, with age (3 or 4 years) and trial order as the between-subjects variables and modality (see, feel, hear, smell, taste) as the within-subjects variable. This analysis revealed no main effect for trial order nor any interaction of trial order with any other variable using children's scores for answers to the How or Show test questions (the analyses were performed for both the lenient and conservative scoring procedures). Thus this factor was not further considered.

How Test Question

According to the conservative scoring method (see Table 1) under which a correct verbal answer needed to be given, 3- and 4-year-olds' overall performance on the How question did not differ significantly. The 4-year-olds answered 57% of the trials correctly ($M = 2.8$, $SD = 1.67$) compared with 37% for the 3-year-olds ($M = 1.8$, $SD = 1.64$).

When a lenient scoring method was used, however, (see Table 1), the 4-year-olds scored no lower than 70% on any modality and their overall performance (82%; $M = 4.0$, $SD = 1.03$) was significantly better than that of the 3-year-olds (47%; $M = 2.3$, $SD = 1.87$),

Table 1 Percentage of Correct Responses for Each Age Group by Modality Condition on the How, Show, and Mr. Potato Head Questions in Study 1

	% Correct Response					
	See	Feel	Hear	Smell	Taste	Overall
How question						
Conservative scoring						
3-year-olds	35	35	32 ^a	47 ^a	37 ^a	37
4-year-olds	50	50	50	75	61 ^b	57
Lenient scoring						
3-year-olds	45	45	53 ^a	47 ^a	47 ^a	47
4-year-olds	80 _c	70	85 _c	100 _c	72 ^b	82 _c
Show question						
Conservative scoring						
3-year-olds	55	50	58 ^a	50 ^b	42 ^a	51
4-year-olds	85	80	68 ^a	85 _c	83 ^b _c	80 _c
Lenient scoring						
3-year-olds	55	65	63 ^a	67 ^b	58 ^a	62
4-year-olds	95 _c	95 _c	90 ^a	95 _c	94 ^b _c	94 _c
Mr. Potato Head question						
3-year-olds	45	50	60	70	55	59
4-year-olds	65	90 _c	90 _c	89.5 ^a	90	85 _c

Note: Means for 4-year-olds identified with subscript c differ significantly, $p < .05$, from the corresponding 3-year-old means.

^a $n = 19$.

^b $n = 18$.

$F(1, 25) = 7.97$, $MSE = 4.69$, $p < .01$. No significant effect for modality was found for either age group.

When children's conservatively scored versus leniently scored responses on the How question were compared, both age groups were found to perform significantly better when responses were scored according to the lenient criteria, 3-year-olds: $t(19) = 2.36$, $p = .03$; 4-year-olds: $t(19) = 3.84$, $p = .001$. It should be noted, however, that even when the lenient scoring criteria was used, answering the How question remained difficult for 3-year-olds—indeed, six 3-year-olds scored 0 over all five trials, whereas no 4-year-old did so.

Simple effects analysis indicated that the 4-year-olds' performance (under the lenient criteria) was significantly better than that of 3-year-olds for the modalities see, $F(1, 33) = 7.75$, $MSE = .20$, $p < .01$, hear, $F(1, 33) = 6.20$, $MSE = .18$, $p < .05$, and smell, $F(1, 33) = 24.24$, $MSE = .12$, $p < .01$, but not for feel and taste.

Under the lenient scoring procedure, for each of the five modalities (with only minor exceptions), verbal responses to the How question (unaccompanied by an action) were the most frequent category of correct responses, accounting for 65% (30 out of 46) of all correct responses among 3-year-olds and 58% (46 out of 80) of all correct responses among 4-year-olds

(see Table 2). This finding suggests that even the 3-year-old children possessed some ability to provide a verbal response to the How question. Four-year-olds were more likely than 3-year-olds to provide a response that included only an action (24 out of 80, or 30% versus 10 out of 46, or 22% of all trials, respectively), and this tendency accounted for the marked significant improvement in their performance when scored according to the lenient criteria (see Table 2). The majority of both the 3-year-olds (9 of 14) and 4-year-olds (15 of 20) who replied with correct verbal or action responses produced a mixture of these response types over the five trials. In both age groups, when action only responses were made, they occurred most frequently for the modality see.

When children responded incorrectly to the How question, they responded with "Because" or "I don't know" approximately one third of the time (32% of all incorrect responses). On the remaining trials, children erred in a number of different and interesting ways. First, on 26% of trials, children simply restated the property of the object (e.g., for see: "Because it is. It is red."). Similarly, on 6% of trials, children responded by performing the appropriate sensory action again, but this response was nonetheless scored as incorrect because their accompanying utterances demonstrated that they were merely performing the action to ascertain the property of the object for a second time. For example, when asked "How did you find out the water is plain?" one 3-year-old replied "It is!" after drinking from the cup again. On 29% of trials, children gave answers that were wholly irrelevant (e.g., for smell: "You can put it in the bath"). Infrequently, these irrelevant answers related in a very general way to the property of the object (e.g., for taste: "Because it's from a tap."). Finally, on 9% of these trials, children erred by stating a sensory action other than the one they had just carried out (e.g., for taste: "'Cause I sawed it was and it is," and for see: "Because I squeezed it and it's too hard").

Show Test Question

According to the conservative scoring procedure (see Table 1), the 4-year-olds performed significantly better than the 3-year-olds, $F(1, 24) = 4.99$, $MSE = 3.19$, $p < .05$ on the Show test question. The 4-year-olds were correct on 80% of all trials ($M = 3.9$, $SD = 1.29$), compared with 51% for the 3-year-olds ($M = 2.45$, $SD = 1.79$). When the lenient scoring procedure was used (see Table 1), the performance of the 4-year-olds improved to 94% ($M = 4.55$, $SD = .95$), representing a significant increase in performance, $t(19) = 2.67$, $p = .015$. Although the lenient scoring criteria also led to a

Table 2 Number of Children Responding Correctly with One of Three Response Patterns to the How and Show Questions by Modality in Each Age Group in Study 1

Scoring Criteria	Response Pattern	See	Feel	Hear	Smell	Taste
How question						
3-year-olds						
Conservative/lenient	Verbal only	5	7	4	7	7
Conservative/lenient	Verbal + action	2	0	2	2	0
Lenient	Action only	2	2	4	0	2
4-year-olds						
Conservative/lenient	Verbal only	5	8	8	14	11
Conservative/lenient	Verbal + action	5	2	2	1	0
Lenient	Action only	6	4	7	5	2
Show question						
3-year-olds						
Lenient	Verbal only	0	3	1	3	3
Conservative/lenient	Verbal + action	2	3	0	1	2
Conservative/lenient	Action only	9	7	11	8	6
4-year-olds						
Lenient	Verbal only	2	3	4	2	2
Conservative/lenient	Verbal + action	3	3	1	3	3
Conservative/lenient	Action only	14	13	12	14	12

Note: Conservative scoring criteria included verbal and verbal + action responses for the How question; action and verbal + action responses for the Show question. Lenient criteria included all three response patterns for both How and Show.

significant increase in performance among the 3-year-olds (62%; $M = 2.95$, $SD = 1.82$), $t(19) = 3.25$, $p = .004$, the performance level of the 4-year-olds remained significantly above that of the 3-year-olds, $F(1, 24) = 8.73$, $MSE = 4.33$, $p < .05$. There was no significant effect for modality using either scoring procedure. Thus, in contrast to children's performance on the How question, for which a significant effect for age was found only when the lenient scoring procedure was used, a significant effect for age was found for the Show question regardless of which scoring method was used. This suggests that the Show question was an easier question for 4-year-old children to answer than the How question.

Simple effects analysis, carried out separately with the data from the lenient and conservative scoring procedures, revealed that, in both cases, the 4-year-olds performed significantly better than the 3-year-olds for the modalities smell, conservative: $F(1, 32) = 5.05$, $MSE = 1.06$, $p < .05$, and lenient: $F(1, 32) = 4.88$, $MSE = .74$, $p < .01$; and taste, conservative: $F(1, 32) = 7.00$, $MSE = 1.44$, $p < .02$, and lenient: $F(1, 32) = 6.70$, $MSE = 1.06$, $p < .02$. Under the lenient scoring system, significant age effects were also seen for the modalities see, $F(1, 32) = 8.91$, $MSE = 1.44$, $p < .01$, and feel, $F(1, 32) = 4.88$, $MSE = .74$, $p < .05$, and a marginally significant effect was found for hear, $F(1, 32) = 4.00$, $MSE = .74$, $p = .054$.

For each of the five modalities, action responses (unaccompanied by a verbal response) were the most frequent category of correct responses (see Table 2), accounting for 69.5% (41 out of 59) of all correct responses among the 3-year-olds and 71% (65 out of 91) of all correct responses among the 4-year-olds. Thus, compared with their responses to the How question, children of both age groups responded to the Show question with considerably more action, as opposed to verbal, responses. This suggests that, especially for the 4-year-old children, the Show question may have provided children with an easier means of demonstrating their ability to identify the source of their property knowledge. The majority of both 3-year-olds (12 of 20) and 4-year-olds (13 of 20) produced a mixture of these two response types over the five trials.

When children responded incorrectly to the Show question, they responded with "Because" or "I don't know" 42% of the time. On the remaining trials, children's errors were similar to those found with the How question. In order of frequency, they included giving a wholly irrelevant answer (28%), restating the property of the object (14%), handing the object to the experimenter in a manner not specific to the experimenter performing any particular sensory action (12%), and performing or describing an incorrect action that would not have led to knowledge of the property (9%).

Mr. Potato Head Test Question

On the Mr. Potato Head test question, the 4-year-olds' performance (85%, $M = 4.2$, $SD = 1.28$) was significantly better than that of the 3-year-olds (59%, $M = 2.95$, $SD = 1.69$), $F(1, 29) = 6.00$, $MSE = 3.23$, $p < .05$ (see Table 1). Simple effects analysis revealed that, in both cases, the 4-year-old children performed significantly better than the 3-year-old children for the modalities feel, $F(1, 37) = 6.36$, $MSE = 1.158$, $p < .02$, and hear, $F(1, 37) = 4.75$, $MSE = .846$, $p < .05$.

Given the clear choice for children in this task among five possible responses (i.e., the five body parts), 3-year-olds' performance can be compared with that expected by chance (i.e., a score of 1 over five trials). Their overall performance was significantly different from that expected by chance, $t(19) = 5.22$, $p < .001$.

Overall, children's performance across the five modality trials on the Mr. Potato Head question was quite similar to their performance on the Show test question, with one exception: both 3- and 4-year-olds showed a 10% to 20% decrement in performance on the see trials for the Mr. Potato Head task (see Table 1). An analysis of children's errors also revealed that this curiously poor performance of children in both age groups on the see trial may have been due to the fact that both the ball and the mouth were (unintentionally) red in color, and the children may have picked the mouth instead of the eyes, because of the color match (e.g., one child responded "It matches"). Apart from this trial, however, children's errors appeared to be fairly randomly distributed throughout all of the modalities (see Table 3).

Pattern of Children's Performance across the Three Test Questions of Study 1

To determine whether the nonverbal test questions posed significantly less difficulty for children, children's performance across the three types of test questions was compared using contrast analysis conducted separately for results according to the conservative or lenient scoring criteria (see Table 1). For both age groups, the omnibus ANOVA revealed a significant effect for question type only when comparing the conservatively scored How and Show questions and the Mr. Potato Head question, $F(1, 19) = 4.14$ and 5.33 , $p < .05$ for 3- and 4-year-olds, respectively, and, therefore, simple effects contrasts were only carried out with respect to children's performance on these questions. Three-year-olds' overall performance on

Table 3 Sensory Modality Chosen in Error When Answering the Mr. Potato Head Question in Study 1

Age	Modality Trial	No. of Children Choosing Erroneous Modality				
		See	Feel	Hear	Smell	Taste
3 years	See		2	1	0	1
	Feel ^a	4		2	2	2
	Hear	0	3		2	1
	Smell	1	1	3		2
	Taste ^a	6	2	2	2	
4 years	See		0	0	0	1
	Feel	3		0	0	0
	Hear	0	2		1	0
	Smell	1	0	2		1
	Taste	3	0	0	1	

^a On one trial, the child refused to make a choice.

the How question (37%) was found to be significantly poorer than their overall performance on the Mr. Potato Head question (59%), $F(1, 19) = 8.3$, $p = .01$. The difference between their overall performance on the Show question (51%) and that on the Mr. Potato Head question only approached significance, $p = .08$. The 4-year-olds' overall performance, in contrast, was significantly better on both the Show and Mr. Potato Head questions (80% and 85% respectively) than on the How question (57%), $F(1, 19) = 6.41$ and 10.83 , $p \leq .02$, respectively.

When individual children's erroneous answers were compared across the three test questions, no pattern could be identified for the majority of children. It was not the case, for example, that children erred on the same modalities. Rather, on the different test questions, children tended to make errors with respect to different modalities.

Discussion

The provision of two nonverbal means of responding in Study 1 improved the performance of the 4-year-old children considerably compared with previous findings, but the performance of the 3-year-old children remained fairly poor. Given the difficulties encountered overall by the 3-year-olds, and by the 4-year-olds with respect to the How question, children in Study 2 were presented with five Mr. Potato Heads, each sporting only one sensory organ. It was hoped that this modification would make it easier for children to consider only one sensory part at a time and to keep separate what particular property information would be accessible to each sense in isolation.

STUDY 2

Method

Participants

Participants were twenty children, age 3;6 to 4;6 ($M = 47.7$ months, $SD = 5.01$, $range = 42-56$ months, 10 girls and 10 boys) recruited from the laboratory preschool at the University of Waterloo, Ontario. These children were largely from White, middle-class families. Three additional children were tested but the data were not used due to experimenter error ($n = 2$) and extreme fussiness ($n = 1$).

Materials

The same five stimulus materials used in Study 1 were used in this study, with the minor modification that for the see trial, a blue (rather than red) ball was used. Four extra trials were also added. On three of these trials greater lengths were taken with respect to the materials and procedures used to help children isolate the one sensory organ responsible for producing their knowledge of the particular property of the object. (1) See-2: A paper cutout of a spotted dragon was used because it was thought that determining the pattern (i.e., striped or spotted) of an object might be more easily recognizable than color as a visual property, and that the use of a two-dimensional object would emphasize the object's being something to look at rather than something to play with. (2) Hear-2: A bell was rung by the experimenter out of the children's sight. Children had to determine whether the experimenter had a toy that made a bell or rattle sound. It was thought that keeping the object out of sight would make it easier for children to isolate their sense of hearing as the source of knowledge. (3) Feel-2: A plastic piggy bank filled with pennies was used so that children could find out its weight (heavy or light) by lifting it up. It was thought that because weight is a property usually accessible only by lifting something, children might recognize feel as the source more easily. Finally, an extra see-control trial was added in which the original red ball was used, to determine whether children's performance in Study 1 had been influenced by the fact that Mr. Potato Head's mouth matched the ball in color.

Procedure

Introduction. As in Study 1, the child and the experimenter sat at a small table and the experimenter told the child, "Today, we are going to play some games." Then, successively, each of the five Mr. Po-

tato Head dolls sporting one of the sensory organs was shown to children and they were asked to name the sensory part on Mr. Potato Head (e.g., nose) and were then told the corresponding name of Mr. Potato Head (e.g., Mr. Nose). The doll was then placed at the far end of the table from where the child was seated, about 60 cm away. By the end of the introduction, all five Mr. Potato Heads stood in a row at the back of the table (their order of introduction and placement in the row was counterbalanced among children). Following this, children were given the following instructions by the experimenter: "I will show you some toys and you follow what I do. Then you tell me which Mr. Potato Head can find out what the toys are."

Experimental task. Following the introduction, all the children received nine experimental trials—the five original trials followed by the four extra trials. The order of the five original trials was counterbalanced as in Study 1, with the remaining four trials always given in the order see-2, feel-2, see-control, hear-2.

The instructions given to children on each of the first five original trials were the same as in Study 1. After the children had imitated the experimenter's action and answered the control question, they were given the Mr. Potato Head test question, "Which Mr. Potato Head can find out the [object] is [the kind that it is]?" (e.g., for the smell trial, "Which Mr. Potato Head can find out the bubble bath is strawberry bubble bath?") This entire procedure was repeated on each trial. For the three additional new property trials, the relevant test questions were: see-2, "Which Mr. Potato Head can find out the dinosaur is a spotted dinosaur?"; hear-2, "Which Mr. Potato Head can find out the toy makes a bell sound?"; and feel-2, "Which Mr. Potato Head can find out the piggy bank is a heavy piggy bank?"

Sensory naming control. Following all nine trials, the children were asked to point out the Mr. Potato Heads who could see, hear, smell, touch, and taste. This task served as a control, in that it showed that children understood the meaning of these sense terms and the fact that each Mr. Potato Head represented one of these sensory modalities.

Results

Children's Performance on the Eight Experimental Trials

Across the eight experimental trials (the *see-control* trial was not included in these analyses), the children performed poorly (see Table 4), picking the correct Mr. Potato Head in only 37.5% of all trials ($M = 3.0$,

Table 4 Percentage of Correct Responses on the Test (Mr. Potato Head) Question in Study 2

Modality Trial	% Correct Response	
	3-Year-Olds	4-Year-Olds
See	10	30
Feel	20	40
Hear	50	50
Smell	20	60
Taste	50	70
See-2	20	60
Hear-2	30	40
Feel-2	0	50
See-control	10	60
Overall	25	50

Note: Children in Study 2 were separated into younger (3,6–3,8) and older (4,1–4,7) age groups ($n = 10$ per age group).

$SD = 2.27$). The correct response rate for the five original trials (the ones that matched those in Study 1, except for the ball being blue rather than red) was 43%. The three extra trials thought to be possibly easier for children did not prove to be so, with children performing worse on hear-2 than on hear and roughly the same on feel-2 as on feel (25% versus 30%). Only on see-2 did children perform twice as well as on see.

Given the poor performance of children overall, the group was separated into a younger (3-year-old) group ($n = 10$; $M = 43.1$ months, $SD = .876$, $range = 42$ – 44 months) and an older (4-year-old) group ($n = 10$; $M = 52.2$ months, $SD = 2.486$, $range = 49$ – 56 months). A two-way repeated-measures ANOVA was conducted with age (3 and 4 years) as the between-subjects variable and modality (see, feel, hear, smell, taste, see-2, feel-2, and hear-2) as the within-subjects variable. The performance of the two age groups was found to differ significantly (see Table 4), with the 3-year-olds averaging 2 out of 8 correct trials ($SD = 1.05$) compared with 4.0 ($SD = 2.75$) for the 4-year-olds, $F(1, 18) = 4.62$, $SD = 2.50$, $p < .05$. There was no significant effect for modality trial nor a significant Modality \times Age interaction. Compared with their overall performance on the Mr. Potato Head question in Study 1 (59% for 3-year-olds and 85% for 4-year-olds), children in both age groups performed more poorly on the Mr. Potato Head question in Study 2 (25% of trials correct for the 3-year-olds; 50% for the 4-year-olds; see Table 4).

As was the case in Study 1, children's errors in Study 2 appeared to be fairly randomly distributed among the eight trials (see Table 5). The only exception appeared to be a tendency to attribute knowledge of the temperature of the water in the swimming

Table 5 Sensory Modality Chosen in Error by Children When Answering the Mr. Potato Head Question in Study 2

Modality Trial	No. of Children Choosing Erroneous Modality				
	See	Feel	Hear	Smell	Taste
See		4	4	4	4
Feel	7		1	3	3
Hear	2	5		2	1
Smell	2	3	3		4
Taste	3	0	3	2	
See-2		3	5	2	2
Hear-2	4	5		1	3
Feel-2	2		5	3	5
See-control		2	2	3	6

pool to Mr. Eyes (see) over any of the other four choices. Children's utterances also revealed little evidence of any pattern in their erroneous responses. For example, one child who picked Mr. Ears (hear) on the feel trial said, "Cause he can hear," and another child who picked Mr. Nose (smell) on the feel-2 trial said, "Cause he can see it."

Children's Performance on the See-Control Trial

Children's performance on the see-control trial with the red ball was approximately equal to their performance on the see trial. Therefore, it is still unclear whether this condition did in fact pose any extra difficulty for children, as suggested in Study 1. Children were more likely, however, to choose Mr. Mouth (taste; with the matching red lips) incorrectly than any other modality (46% of all incorrect trials). When the blue ball was used on the see trial, children's errors were equally distributed across the four incorrect choices.

Children's Performance on the Sensory Control Questions

Both age groups performed at ceiling when asked to point to the Mr. Potato Head that could see, feel, hear, smell, or taste (100% for the 3-year-olds and 99% for the 4-year-olds). Thus, children's poor performance was not due to their not knowing the sensory actions corresponding to each sensory organ.

Discussion

The separation of the five sensory organs among five Mr. Potato Heads did not appear to improve children's performance at all, and in some cases appeared

to have impaired their performance more than when only one Mr. Potato Head with all five sensory parts was used. Interestingly, despite their inability to state which sensory part would result in knowledge of a given property, children experienced no difficulty pairing each of the five anatomical sensory organs with its associated sensory action.

GENERAL DISCUSSION

Overall, the 4-year-olds in both our studies performed significantly better than the 3-year-olds on all test questions except the How question of Study 1 when it was scored conservatively. Apart from their performance on the latter question, 4-year-olds' performance on all other questions in Study 1 was good, ranging from 80% to 94%. In contrast, 3-year-olds' performance only ranged from 47% to 62%. Children's poor performance on the Mr. Potato Head test question of Study 2 was unexpected, and two possible reasons are offered. First, contrary to our intention, the use of five separate dolls may have made the situation more distracting for children. Second, children's performance on the Mr. Potato Head question in Study 1 may have been better than that in Study 2 because in Study 1, the How and Show questions preceded the Mr. Potato Head task, possibly providing children with more time to consider the source of their knowledge and to apply this understanding when asked the Mr. Potato Head question.

Nevertheless, it is clear from Study 1 that the 4-year-olds benefited from being able to demonstrate their knowledge in nonverbal form. First, their performance on the Show and Mr. Potato Head questions was significantly better than their performance on the How question when it was scored conservatively to include only verbal responses. Second, when the How question was scored leniently so as to include action responses, their level of correct performance rose significantly from 57% to 82%, and their performance among the three test questions was no longer found to differ significantly (see Table 1). In contrast, 3-year-olds benefited less clearly from the opportunity to demonstrate their understanding nonverbally. First, a significant difference in performance was found for the How question (scored conservatively) versus the Mr. Potato Head question but not for the How question versus the Show question. Second, although on both the How and Show questions the use of the lenient scoring criteria produced a significant increase in performance, in both cases the performance of the 4-year-olds remained significantly above that of the 3-year-olds.

The fact that, given the nonverbal response options, an improvement in performance was observed

more prominently among the 4-year-olds than the 3-year-olds suggests, importantly, that the developments taking place during this time period (i.e., from age 3 to age 4) with respect to an understanding of aspectuality are not just a matter of increased verbal competence. The fact that the 4-year-olds performed consistently and significantly better than the 3-year-olds, and that no significant modality effects were found, may be indicative of a more dramatic conceptual shift occurring between the ages of 3 and 4 years with respect to children's understanding of the aspectuality of knowledge. In addition, 4-year-olds' near-perfect performance on the Show question, as opposed to the Mr. Potato Head question, may also be an indication of a more general tendency for children to explain action more readily and easily than they predict action, as has been found with respect to false belief understanding (Moses & Flavell, 1990; see also Fodor, 1992).

Turning to the 3-year-olds, how can the understanding that they possess, given these results, be characterized? Looking at their performance on the Show question may provide us with the clearest picture. Specifically, almost half of the time (when scored conservatively), the 3-year-olds could not repeat the action they carried out seconds earlier when asked to show how they had identified the object's property. This inability to demonstrate the action leading to their knowledge is also consistent with the finding that when the How question was scored leniently, 3-year-olds performance, although it improved significantly, remained significantly below that of 4-year-olds (see Table 1). These results extend previous findings with respect to 3-year-olds in an important way: They demonstrate that even when asked about their own knowledge and experiences, and given a nonverbal means by which to answer the question, 3-year-olds could do so only about half of the time, and performed consistently worse than 4-year-olds.

The presentation of our findings in this format—a written journal article—makes it hard to convey the difficulty 3-year-olds had in answering questions about the source of their knowledge of the properties in question. Nor is it easy to convey here how odd children's responses often appeared. It would not be inconsistent with what we observed to say that many 3-year-olds appeared entirely unaware of how their own sensory actions were related to the property knowledge they had gained only seconds earlier. As we have tried to show through a description of some children's errors, children not only responded with irrelevant answers (which could be expected if they simply did not know the answer), but also at times by demonstrating or naming an action that could not possibly have led to the knowledge in question. To

watch a child sniff a swimming pool and tell you that that is how they found out it contained cold water is quite striking! As noted in O'Neill and Gopnik (1991), these answers seem all the more unusual when it would have been possible for children to answer correctly by using the simple strategy of referring back to the action they had just carried out, even without explicitly understanding the significance of that action or its relation to their knowledge of the property.

Despite these clear instances of a lack of understanding, the results show that 3-year-olds' performance was significantly above chance on the Mr. Potato Head question of Study 1 and that their performance significantly improved when the How and Show questions were scored leniently. These findings suggest that 3-year-olds showed some ability to succeed on the study tasks. The question of interest, however, is by what route this success was achieved and whether it was similar to that used by 4-year-olds. The fact that the 4-year-olds benefited so clearly from the nonverbal response options in Study 1, and showed consistently high performance across all three questions when scored leniently, suggests that their understanding is a robust one—although not necessarily one that they could easily verbalize. It could perhaps be argued that 4-year-olds' nonverbal responses on the How and Show questions reflected the application of a simple rule to repeat the action they just did, without an understanding of the relation of their action to their knowledge of the property. We would argue, however, that if this were the case, then their performance on the Mr. Potato Head task, where this rule could not have been applied, would presumably have been poorer than their performance on the How and Show questions. This was not the case, and thus we would argue that the nonverbal route allowed 4-year-olds to express an understanding that reflects more than just the application of a simple rule to describe or repeat the action just carried out.

In contrast, given the smaller improvement in performance with the nonverbal tasks among the 3-year-olds, their understanding appears to be limited to a more haphazard and nonrobust recognition or understanding of the association between their past sensory activity and their state of knowledge regarding the particular property of the object. Individual 3-year-old children may, on certain trials, show some ability to recognize the source of their property knowledge if the sensory experience or property is, for some reason, particularly salient or memorable to them. (Given that no modality effects were ever found, however, it cannot be said that certain sensory experiences were more salient to the children as a group.) This may ac-

count for their above-chance performance overall. For these children, the attainment of a more robust understanding lies not merely in gaining verbal competence but also in gaining an understanding of the necessary relation between sensory action and knowledge of a property across all five modalities.

It should be remembered that previous studies have shown that 3-year-olds have some ability to identify the source of their knowledge when learning the identity or contents of a box. In such cases, it is perhaps easier for 3-year-olds to reflect on what activity they carried out to effect a change from a state of complete ignorance concerning an object or event to a state of knowledge about the identity of an object or event. Even given such simpler tasks, however, in no previous study have 3-year-olds performed well in identifying the source of their knowledge across all modalities presented to them.

Children's difficulties with identifying the source of their information, especially among 3-year-olds, has been explained in terms of a deficit in source memory (e.g., Gopnik & Graf, 1988; O'Neill & Gopnik, 1991; Perner 1990, 1991, 1992). For example, it has been argued, most forcefully perhaps by Perner (1990, 1991, 1992), that children's difficulty should be understood in terms of their being unable to "remember" the origin of their knowledge, perhaps as a result of deficits in episodic memory (e.g., Neisser, 1978; Nelson & Gruendel, 1981).

In light of the present results and additional findings and distinctions made by neuropsychologists, it is felt that this explanation for children's difficulty on tasks such as the ones in the present research needs to be revisited and refined. It is now recognized that varying degrees of source amnesia exist, with some patients demonstrating a milder form in which they are unable to recall the source of acquired information when a delay is introduced, and other patients demonstrating a more severe form in which source amnesia occurs almost immediately after the learning event (e.g., Gene, as studied by Schacter, Harbluk, & McLachlan, 1984, and discussed in Schacter, 1996). Given that in the present studies tasks the children were asked about the source of their knowledge immediately following apprehension of the property information, their difficulty in stating the source of their knowledge would appear to be comparable with the more severe cases of source amnesia reported in the literature. Moreover, it has been suggested that amnesiacs with signs of frontal lobe dysfunction may have deficits of processing resource that restrict their ability to encode simultaneously an item and its context (e.g., Rabinowitz, Craik, & Ackerman, 1982). Thus, rather than explaining children's difficulty in terms of

an inability to remember the source of their knowledge, their deficit is perhaps more accurately described as an inability to become explicitly or declaratively aware of the source of perceptual experiences, perhaps as a result of an inability to process the source at the time of learning the perceptual information.

Another reason to believe that children's inability to recall the source of perceptual knowledge in the present studies may be comparable to more severe cases of source amnesia is that children's answers at times appeared to be similar to the types of confabulation noted to occur in conjunction with severe amnesia (e.g., Moscovitch, 1995; Schacter, 1996; Schacter et al., 1984). Among such patients, their failures of source memory are often accompanied by quite elaborate (but well-intended) confabulations and the invention of implausible experiences to support the confabulations. Moscovitch (1995) argues that these confabulations may be largely the result of a relatively automatic associative retrieval process rather than a more laborious and voluntary strategic retrieval process. That is, during associative retrieval, all types of experiences automatically spring to mind in response to environmental cues. We would note that children's incorrect responses in these studies often appeared to fit such a description, occurring quite spontaneously and in response to irrelevant cues in the situation (e.g., the red mouth of Mr. Potato Head). It remains for researchers to discover in future work whether these responses reflect a retrieval of this information, or are simply responses generated from cues in the current environment.

It may also be of interest that although source memory deficits are thought to have their neurological basis in the frontal lobes (e.g., Craik, Morris, Morris, & Loewen, 1990; Rybash & Colilla, 1994; Schacter et al., 1984), extensive confabulation tends to be seen only when lesions penetrate to the inner (ventromedial) regions of the frontal lobes and damage the nearby basal forebrain (Moscovitch, 1995). Because the frontal lobes are composed of numerous subregions that perform different functions (Damasio, 1994; Shimamura, 1995), it is possible that young preschool children's inability to state the source of their property knowledge in tasks such as those presented in this article may be mediated by a different region of the frontal lobes that is also implicated in more severe cases of source amnesia and may differ in nature from the frontal region subserving what has more generally been referred to as "source memory deficit."

Understanding what types of information are accessible through different sensory modalities is generally regarded as an important topic to be introduced by teachers and mastered by children as part of

their early elementary science programs (Massey & Roth, 1997). Further research is needed to determine the typical time course for understanding different aspects of modality-specific knowledge, the factors involved that can present difficulties for children, and methods for facilitating children's acquisition of this knowledge. It is clear that the development of a full understanding of knowledge—which encompasses both an understanding that evidence is a necessary accompaniment of knowledge and an understanding of how different beliefs are based on different sensory evidence—is a protracted one, reaching beyond the preschool years and into the elementary school years. We believe a dramatic and qualitative shift in this understanding takes place between the ages of 3 and 4, and that this shift accounts for the significantly better performance of the 4-year-olds compared with the 3-year-olds on many of the test questions in the present research. Whether further dramatic transitions are seen again at a later age, or whether a fairly continuous pattern of development in this ability is seen after this age, are topics for future research.

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