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Three- and four-year-olds spontaneously use others' past performance to guide their learning

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Abstract

A wealth of human knowledge is acquired by attending to information provided by other people – but some people are more credible sources than others. In two experiments, we explored whether young children spontaneously keep track of an individual's history of being accurate or inaccurate and use this information to facilitate subsequent learning. We found that 3- and 4-year-olds favor a previously accurate individual when learning new words and learning new object functions and applied the principle of mutual exclusivity to the newly learned words but not the newly learned functions. These findings expand upon previous research in a number of ways, most importantly by showing that (a) children spontaneously keep track of an individual's history and use it to guide subsequent learning without any prompting, and (b) children's sensitivity to others' prior accuracy is not specific to the domain of language.

Keywords: Theory of mind; Mental state attribution; Word learning; Function learning; Source monitoring; Memory; Impression formation; Mutual exclusivity; Epistemic reasoning

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1. Introduction

A tremendous amount of what humans learn is learned from other people. Indeed, social transmission, either implicit or explicit, is the main route through which humans learn about language, culture, science, religion, and human relations. Typically-developing children avidly seek out information provided by others, starting with their expressions and actions, and then, as they get older, learning from information conveyed through speech (for discussion, see Baldwin, 2000; Bloom, 2000; Tomasello, Carpenter, Call, Behne, & Moll, 2005).

Such reliance on other people poses a unique set of challenges, however. Although a baby is prudent to rely on the cues provided by his or her parent – being more willing to crawl over a visual cliff if the parent makes supportive expressions and sounds, for instance (Vaish & Striano, 2004) – it would be maladaptive for children and adults to indiscriminately trust all information that others provide. Humans make mistakes; they trick; they lie; they have different levels of knowledge and different areas of expertise; and they offer information even when they are uncertain (see Callanan, Sabbagh, Perez, & Cervantes, 1995). Hence, learners are faced with the task of determining when, and if, someone is a credible information source.

Sabbagh and Baldwin (2001) found that 3- and 4-year-olds are sensitive to explicit verbal cues about the credibility of a source. When taught novel words by a speaker who verbally conveyed his knowledge or ignorance about the word's referent, (e.g., the speaker said, "You know, I'd like to help my friend Birdie and I know just which one's her blicket." versus "You know, I'd like to help my friend Birdie, but I don't know what a blicket is. Hmmm. Maybe, it's this one."), they were more likely to learn the word from the speaker who claimed certainty. Relatedly, Chris Moore and his colleagues (Moore, Bryant, & Furrow, 1989; Moore & Davidge, 1989) have found that 4-year-olds, but not 3-year-olds, are sensitive to explicit linguistic markers of epistemic states (e.g., 'know' versus 'think').

Can children use less explicit cues to credibility – such as the speaker's prior history of being correct or incorrect – to determine who is the most credible? All else being equal, it is a useful heuristic to assume that someone who has been correct in the past is more likely to be correct in the future than someone who has been incorrect in the past. Do young children appreciate this and can they use this information to facilitate the learning process? Recent research suggests that they can.

Koenig, Clement, and Harris (2004) showed 3- and 4-year-old children video clips in which an actor asked questions of two informants, one who consistently responded correctly (e.g., calling a ball "a ball") the other who consistently responded incorrectly (e.g., calling a ball, "a shoe"). Children were asked to identity the person who said something right and the person who said something wrong. The children then observed the actors label a single object with different names, and were asked which was correct. For instance, the previously correct speaker would call the object a "mido", the previously incorrect one would call it a "toma", and children would be asked: "Can you tell me what this is called, a mido or a toma?". Koenig et al. (2004) found that 3-year-olds and 4-year-olds who passed the explicit questions regarding which informant was right/wrong were significantly more likely to choose

what the accurate informant said as the label for the novel object, suggesting they understand that a person's prior credibility is a useful cue to a person's future credibility (see also Clément, Koenig, & Harris, 2004; Pasquini, Corriveau, Koenig, & Harris, 2007).

In follow-up studies, Koenig and Harris (2005) explored whether, in addition to endorsing information from the most credible source, children could also use a person's past performance to make related decisions (such as choosing to *seek out* new information from the previously accurate person). In this procedure 3- and 4-year-olds were able to distinguish the accurate and inaccurate speakers when asked, 'Which one was (not) very good at answering questions?', but only the 4-year-olds used that judgment to: (a) predict their future assertions, (b) seek information from the more accurate speaker, and (c) endorse the more accurate speaker's claims. Koenig and Harris (2005) also noted an important distinction between someone with a history of being *inaccurate* (e.g., calling a ball 'a book') and someone with a history of being *ignorant* (e.g., saying 'I don't know' when asked what a ball is called). They found that when the alternative speaker was inaccurate (Experiment 1) 3-year-olds did not favor the previously accurate speaker, but when the alternative speaker was *ignorant* (Experiment 2), 3-year-olds directed their questions to, and preferred to learn from, the accurate speaker (see Koenig & Harris, 2005 for a discussion).

More recently, Jaswal and Neely (2007) provided another demonstration of children's ability to use a person's past performance when choosing the best source of information. They found that when given a choice to learn new words from either a child or an adult – both of whom had a history of being accurate – children tended to choose the words provided by the adult. However, when given a choice to learn new words from either a child who had a history of being accurate or an adult who had a history of being inaccurate, children preferred to learn the words provided by the child. In other words, prior accuracy trumped age.

For this sensitivity to previous accuracy to play an important role in real-world learning, however, at least four prerequisites must be met. First, children must be sensitive to others' mistakes. That is, they will need to detect when others offer inaccurate information. Second, children need to possess at least an implicit appreciation that a person's prior competence is a useful indicator of that person's future competence. Third, they must be able to keep person-specific information about prior accuracy separate from accuracy information about other individuals and be able to use it to evaluate new information from those same individuals. Importantly, for these abilities to have much influence on real-world learning a fourth condition is essential: Children must spontaneously keep this track record and spontaneously use it to facilitate subsequent learning. It is not sufficient, after all, that they *can* capitalize on the fact that someone is 'good' or 'not very good' at answering questions when prompted by an experimenter; for this capacity to impact learning outside of the laboratory, children must spontaneously track and store this information and choose to use it in the normal course of social interaction.

The first prerequisite – a sensitivity to others' mistakes – emerges relatively early (at least in the domain of language). Pea (1982) demonstrated that 24- to 30-month-old children will say "no" to speakers who mislabeled visible objects, and Koenig

and Echols (2003) demonstrated that children as young as 16-months of age looked longer at speakers who mislabeled a series of common objects.

The second and third prerequisites – an implicit understanding of the relationship between past behavior and future behavior, and an ability to use person-specific information about prior accuracy to aid the learning of new information from that person – were shown in Koenig et al. (2004) study described above. They found that 3- and 4-year-olds who passed the explicit questions regarding which informant was right/wrong were significantly more likely to choose what the accurate informant said as the label for a novel object. These results suggest that young children appreciate, at some level, that a person's prior competence can be a useful cue to a person's future competence, and can use person-specific information to guide future learning (at least when they are prompted to explicitly note the person's prior accuracy).

The fourth prerequisite has not yet been explored. None of the research to date has addressed whether children naturally hold person-specific information about previous accuracy in mind and spontaneously use it in the course of subsequent learning. In the studies described above, the children were always explicitly asked about the speaker's performance prior to being tested on new items (e.g., the experimenter said, 'One of these people was not very good at answering these questions. Which one was not very good at answering questions?). It is unclear whether children would utilize the speaker's previous history to guide their learning if this priming was not provided. Indeed, Dunfield and Fitneva (2007) found that even after a single trial in which one person was correct and the other incorrect, 4-year-olds subsequently sought information from the previously correct speaker, but, they only did so when given a trait-like prompt such as 'Which one was (not) very good at answering the question?'.

Moreover, it is unclear from the studies that have explored children's sensitivity to a person's prior accuracy whether the children are actually learning the new information. It is possible that in these studies, the child is simply siding with the individual who was correct in the past. For example, they might have adopted a heuristic such as "say whatever the person who is good at answering questions says", or "ignore whatever the person who is not good at answering questions says" without actually learning the new word. For instance, children who were asked, "Can you tell me what this is called, a mido or a toma?", usually responded with the name given by the previously accurate informant ("mido"), but they might have done so without storing "mido" in long-term memory; that is, they might have done so without learning the new word.

To address this concern, the experiments reported here include two sorts of test trials. There is a 'Preference Condition', similar to the studies described above, where the correct answer is the same answer given by the previously accurate speaker. But there is also a more difficult 'Contrast Condition'. In this condition, two objects are placed in front of the child and the previously accurate speaker names one of them "a ferber" (for example), and the previously inaccurate speaker names the other object with the same name: "a ferber". Children are then asked "Where's the cheena?", cheena being a word that they have not previously heard. We know from other

research that children of this age are biased to assume that different words refer to different objects (i.e., the constraint of 'mutual exclusivity'; see Markman & Wachtel, 1988; see also Byers-Heinlein & Werker, 2006; Golinkoff, Mervis, & Hirsh-Pasek, 1994; Hall & Graham, 1999; Merriman & Bowman, 1989; Mervis, Golinkoff, & Bertrand, 1994). Hence, if children have fully encoded that "ferber" refers to the object labeled by the previously accurate speaker then they should make the inference that this new word "cheena" refers to the other object. This experiment addresses the robustness of the learning of this socially-transmitted information by capitalizing on children's tendency to treat word labels as mutually exclusive.

In sum, the following experiments address whether 3- and 4-year-old children spontaneously keep track of an individual's history of providing accurate or inaccurate information and use this person-specific information to guide their subsequent learning.

2. Experiment 1

2.1. Method

2.1.1. Participants

Forty children from middle-class families participated in the current study: Twenty 3-year-olds (8 Males; 12 Females; M = 41 months; range = 34 months to 47 months) and 20 4-year-olds (12 Males; 8 Females; M = 54 months; range = 49 months to 59 months). Sixty-three percent were White, 5% were Black, and 33% were Asian.

2.1.2. Materials

The materials consisted of four common objects, eight novel objects and two hand puppets (one child-like girl "Jenny"; one child-like boy "Ben") with moveable mouths who served as the accurate and inaccurate speakers. The common objects were the following: a red toy car, an orange miniature basketball, a brown plastic horse, and a red toy spoon. The eight novel objects were an odd-shaped fishing lure, a gadget for clipping eyeglasses to a visor, a plastic egg-holder, a silver waterproof container for matches, a rubber soap holder, a yellow garlic press, a wire gadget for displaying ornamental plates and a plastic object from a chemistry set.

2.1.3. Procedure

The children participated one at a time either in a university laboratory or in a quiet area of their local childcare center. The children were first introduced to the two puppets. The experimenter said, "I brought a whole bunch of fun things with me today and I also brought my two puppet friends: Ben and Jenny. Would you like to meet Ben and Jenny?" Each puppet then took a turn introducing him or herself to the child by saying, "Hi, I'm Ben (or Jenny)! What's your name? Nice to meet you _____!". All children then participated in two phases: A 'History Phase' followed by a 'Testing Phase'.

2.1.4. History phase

During the History Phase, the experimenter said "Ok, Let's see what we have in this bag. Let's show these to Ben and Jenny. We'll let Ben and Jenny talk now and we'll just watch and listen, ok?". The children then observed the two puppets label the four common objects. One puppet labeled all four common objects correctly by referring to the ball saying, "I think that's a ball. Yeah, that's a ball.", then referring to the horse saying, "I think that's a horse. Yeah, that's a horse." and so on for the spoon and the car. The other puppet labeled all four common objects incorrectly by referring to the ball saying, "I think that's a book. Yeah, that's a book." and referring to the horse saying, "I think that's a cat. Yeah, that's a cat." and similarly labeling the spoon 'a cup' and the car 'a shoe'. Ben always spoke before Jenny, in both the history and testing phases. For half of the children, Ben was the accurate speaker; for the other half, Ben was the inaccurate speaker.

2.1.5. Testing phase

Immediately following the History Phase children were presented with four pairs of novel objects. Each pair of objects was placed in front of the child one at a time and the children observed as the previously accurate speaker labeled one member of the pair and the previously inaccurate speaker labeled the other member of the pair.

The testing phase consisted of two conditions: A 'Preference Condition' and a 'Contrast Condition' (the order of which was counterbalanced). During the Preference Condition, the experimenter said, "Ok, what else do we have? Let's show these two things to Ben and Jenny.", and placed a pair of novel objects in front of the children. Then said, "Look Ben, What's this?" picking up the first object in the pair. Ben replied, "I think that's a ferber. Yeah, that's a ferber. Do you see the ferber?" (then looking at the child). The experimenter then said, "Look Jenny, What's this?" picking up the second object in the pair. Jenny replied in the same manner, "I think that's a ferber. Yeah, that's a ferber. Do you see the ferber?" (then looking at the child). Following this, the experimenter closed her eyes (to avoid inadvertently giving any eye-gaze cues) and cupped her hands in front of the child in a 'give me' gesture and asked, "Can you give me the ferber? Where's the ferber?". This was repeated for a second pair of novel objects using the word 'turly'.

The 'Contrast' Condition was the same except that after the two speakers had offered the same label to different objects, for instance, one calling Object A 'a koba' and the second calling Object B 'a koba' the experimenter then closed her eyes and cupped her hands in front of the child and asked for 'the modi' (which was a word the children had not heard before during the procedure). This was repeated for a second pair of novel objects with the puppets using the word 'gilly' and the experimenter asking for the 'cheena'.

After the main testing phase, children were shown the four common objects used during the history phase and asked, "What's this called?" for each of them. This was to ensure that they were indeed familiar with the labels for the common objects. Indeed, children offered the correct label for each common object 100% of the time.

2.2. Results and discussion

A 2 (Condition) × 2 (Age) × 2 (Gender) × 2 (Speaker Order) × 2 (Condition Order) Mixed Analysis of Variance (ANOVA) was conducted with Condition (Preference vs. Contrast) as a within-subjects variable and Speaker Order (Accurate vs. Inaccurate first), Condition Order (Preference vs. Contrast first), Age, and Gender, as between-subjects variables. The number of trials that the participant chose the object referred to by the previously accurate speaker served as the dependent measure. This is converted to percentages below for ease of interpretation. Recall that children who have spontaneously tracked the speakers' prior accuracy and understand that an individual's prior accuracy can be useful for predicting his or her future credibility should choose the object labeled by the previously accurate speaker in the Preference Condition. Furthermore, they should be more likely *not* to choose the object labeled by the previously accurate speaker in the Contrast Condition. If they have robustly mapped the word to the object that the accurate speaker labeled, they should choose the object labeled by the previously *inaccurate* speaker when the experimenter asks for a contrasting label.

The omnibus ANOVA did not reveal a main effect of age, $F(1,25) = 1.256$, $p = .273$, n.s., nor any interactions with age. As predicted it revealed a significant main effect of Condition, $F(1,25) = 12.27$, $p < .005$, indicating that children selected the object referred to by the previously accurate speaker more often in the Preference Condition ($M = 73\%$, $SD = 36\%$) than in the Contrast Condition ($M = 36\%$, $SD = 41\%$). Furthermore, children's tendency to choose the object referred to by the previously accurate speaker was significantly above chance in the Preference Condition, $t(39) = 3.984$, $p < .001$, and significantly below chance in the Contrast Condition, $t(39) = -2.131$, $p < .05$. See Fig. 1.

All other main effects and interactions were non-significant except an unanticipated Condition by Speaker Order interaction, $F(1,25) = 6.087$, $p < .05$. This Condition by Speaker Order interaction reflected that children were more likely to show an effect of condition (i.e., choosing the object labeled by the previously accurate speaker in the Preference Condition and being biased against it in the Contrast Condition) when the accurate speaker spoke last (Preference $M = 81\%$, Contrast $M = 17\%$) compared to when the accurate speaker spoke first (Preference $M = 63\%$, Contrast $M = 45\%$). One explanation for this interaction is that when the first speaker provides the inaccurate labels in the history phase (which is somewhat unexpected) the accuracy of both speakers is made more salient to the child, leading to better performance. A related explanation appeals to the pragmatics of the situation. Perhaps inaccurate-then-accurate is a more logical order to children than accurate-then-inaccurate. Children might assume, for instance, that if one speaker offers the wrong name and then a second speaker, in the presence of the first, offers the right one, then this second remark is a correction of the first. Accurate-then-inaccurate might be harder to make sense of, leading to less robust responses.

These results show that 3- and 4-year-olds spontaneously keep track of an individual's history of accuracy and are motivated to use this information to evaluate the accuracy of subsequent words provided by those individuals. Specifically, the chil-

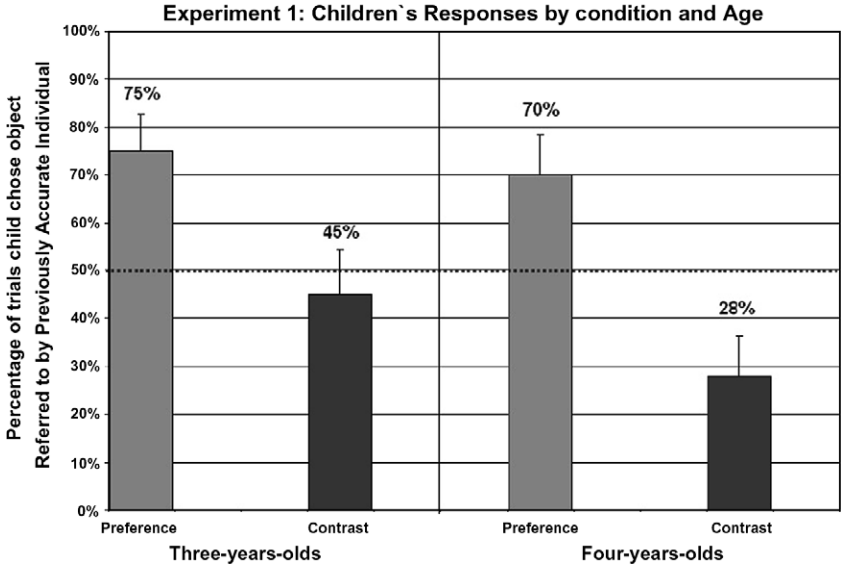

Fig. 1. Experiment 1: Children's responses by condition and age: Mean percentage of trials children chose the object labeled by the individual who was previously accurate at labeling common objects.

dren were more likely to accept the referent of a novel word that was given by a previously accurate labeler than by a previously inaccurate labeler and they did so without being primed about who was 'good' or 'not very good' at answering questions in the past. They were also *less* likely to apply a novel name provided by the experimenter to an object already named by a previously accurate speaker, suggesting they had robustly encoded the word provided by the previously inaccurate speaker.

A further goal of our research was to use this more sensitive measure to explore children's appreciation of a person's accuracy outside of the domain of word learning. We conjectured that this sensitivity to others' competence is not driven by a language-specific mechanism, but rather stems from a general learning mechanism that children can use to improve the efficacy of their learning. Specifically, we examined whether children are sensitive to an individual's history of being knowledgeable of the typical functions for common objects.

Moreover, using the same design to explore children's function learning allowed us to test whether children rigidly apply the principle of mutual exclusivity to functions for novel objects. While objects can have many non-functional properties (even 3-year-olds are aware, for instance, that the very same thing can both be'from an uncle' and'used in the kitchen'; see Diesendruck & Markson, 2001) objects tend to have single primary functions. Screwdrivers are for turning screws, coffee machines make coffee, toothbrushes are for cleaning teeth, and so on. There are exceptions to this generalization, including complex artifacts like computers, multi-purpose artifacts like clock radios, and seemingly non-functional artifacts like paintings, but, for the most part, adults encode a one-to-one mapping between artifacts and func-

tions. Adults find it easy to answer the question "What's it for?", and are vulnerable to functional fixedness (i.e., their knowledge of an objects' primary function interferes with their ability to think of alternative functions for it; Adamson, 1952; Duncker, 1945). There is some debate, however, whether preschool children also tend to conceptualize objects as being primarily for one purpose. Some researchers maintain that preschool children do not appear to hold rigidly to the notion of one-to-one mappings between artifacts and functions. In particular, they do not seem to suffer from functional fixedness (Defeyter & German, 2003; German & Defeyter, 2000; German & Barrett, 2005). Other researchers, however, have found evidence of mutual exclusivity for functions (e.g., Casler & Kelemen, 2005). We will discuss possible explanations for these equivocal findings in the Discussion. In light of this controversy it is an open question whether the same mutual exclusivity effect that we found for newly learned words would appear for newly learned functions.

3. Experiment 2

In Experiment 2, we were interested in whether children would spontaneously keep track of a person's history of being accurate or inaccurate in a domain other than word learning – in this case, the typical functions of objects. The design here parallels that of Experiment 1, including the presence of the Contrast Condition. Here, however, there was no clear prediction about how children would respond in the Contrast Condition given that this experiment involved functions instead of words. The Contrast Condition was included to make the experiment as similar as possible to Experiment 1 and to control again for low-level explanations of 'correct' responding in the Preference Condition. Note that even if children do not show a mutual exclusivity effect in the Contrast Condition this condition still serves to rule out a more simplistic explanation of the previous results. That is, if children fail to show a preference for the object referred to by the previously accurate speaker in the Contrast Condition then a low level heuristic of ('side with the good answerer') cannot explain the results.

3.1. Method

3.1.1. Participants

Forty children from middle-class families participated in the current study: Twenty 3-year-olds (8 Males; 12 Females; $M = 44$ months; range = 38 months to 48 months) and 20 4-year-olds (11 Males; 9 Females; $M = 54$ months; range = 49 months to 59 months). Eighty percent were White, 12.5% were Black, and 7.5% were Asian.

3.1.2. Materials

Same as in Experiment 1 except the toy car and plastic horse were replaced by a comb and a toothbrush so that each of the common objects would have a typical function known by children.

3.1.3. Procedure

Like the children in Experiment 1, the children participated one at a time either in a university laboratory or in a quiet area of their local daycare center. The children were first introduced to the two puppets. The experimenter said, "I brought a whole bunch of fun things with me today and I also brought my two puppet friends: Ben and Jenny. Would you like to meet Ben and Jenny?" Each puppet then took a turn introducing him or herself to the child by saying, "Hi, I'm Ben (or Jenny)! What's your name? Nice to meet you_____!" All children then participated in two phases: A 'History Phase' followed by a 'Testing Phase'.

3.1.4. History phase

During the History Phase, the experimenter said, "Okay, let's see what we have in this bag. Let's show these to Ben and Jenny. We'll let Ben and Jenny talk now and we'll just watch and listen, okay?". The children then observed two puppets state functions for four common objects (i.e. a ball, toothbrush, spoon, and comb). One puppet correctly provided the typical functions of all four common objects by referring to the ball saying, "I think that's for playing with. Yeah, that's for playing with", then referring to the toothbrush saying, "I think that's for brushing your teeth. Yeah, that's for brushing your teeth." and so on for the spoon and the comb. The other puppet incorrectly stated the typical functions of all four common objects by referring to the ball saying, "I think that's for washing your clothes. Yeah, that's for washing your clothes." and referring to the toothbrush saying, "I think that's for cleaning your face. Yeah, that's for cleaning your face." and so on for the spoon (for 'tying your shoe') and comb (for 'wiping your hands'). Note the puppets always referred to the object as "that" not with its label (e.g., spoon). As in Experiment 1, Ben always provided the functions first, but whether Ben or Jenny served as the 'accurate' individual or the 'inaccurate' individual was counterbalanced (hence, whether Object A or B below was the 'correct' object for serving a given function was also counterbalanced).

3.1.5. Testing phase

Immediately following the History Phase children were presented with four pairs of novel objects. Each pair of novel objects was placed in front of the child one at a time and the children observed as the accurate speaker stated the function of one member of the pair and the inaccurate speaker stated the *same* function but applied it to the *other* member of the pair.

Like Experiment 1, the testing phase consisted of two conditions: A Preference Condition and a Contrast Condition (the order of which was also counterbalanced). Children heard the puppets state the functions for the novel objects: During the Preference Condition, the experimenter said, "Okay, what else do we have? Let's show these two things to Ben and Jenny.", and placed a pair of novel objects in front of the child. Then said, "Look Ben, what's this for?" picking up the first object in the pair. Ben replied, "I think that's for cleaning a toaster. Yeah, that's for cleaning a toaster. Do you see this? It's for cleaning a toaster." The experimenter then said, "Look Jenny, what's this for?" picking up the second object in the pair. Jenny

replied, "I think that's for cleaning a toaster. Yeah, that's for cleaning a toaster. Do you see this? It's for cleaning a toaster." Following this, the experimenter closed her eyes and cupped her hands in front of the child in a 'give me' gesture and asked the child, "Can you give me the one that's for cleaning a toaster? Where's the one that's for cleaning a toaster?" This was then repeated for a second pair of novel objects using the function "for fixing a TV".

The Contrast Condition was identical except that after the two speakers had offered the same object function to different objects, for instance, one saying that Object A is "for opening boxes" and the second saying that Object B is "for opening boxes", the experimenter closed her eyes and cupped her hands in a 'give me' gesture and asked for the object that is "for washing your hands" (i.e., a function that the children had not heard before during the procedure). This was then repeated for a second pair of novel objects with the puppets stating the function of the objects as "for baking a cake" and the experimenter asking for the object that is "for cleaning a boat".

To ensure the four common objects and functions used during the History Phase were indeed familiar to each child, the children were asked at the end of the four trials, "What's this for?" for each of the common objects. Indeed, children offered the correct functions for each common object 100% of the time.

3.2. Results and discussion

A 2 (Condition) × 2 (Age) × 2 (Gender) × 2 (Speaker Order) × 2 (Condition Order) Mixed Analysis of Variance (ANOVA) was conducted with Condition (Preference vs. Contrast) as a within-subjects variable and Speaker Order (Accurate vs. Inaccurate first), Condition Order (Preference vs. Contrast first), Age, and Gender, as between-subjects variables. The number of trials that the participant chose the object referred to by the previously accurate speaker served as the dependent measure. This is converted to percentages below for ease of interpretation.

The omnibus ANOVA did not reveal a main effect of age, $F(1,25) = .846$, $p = .366$, n.s., nor any interactions with age. A significant main effect of condition was revealed, $F(1,25) = 5.78$, $p < .05$, indicating that children selected the object referred to by the accurate individual more often in the Preference Condition ($M = 68\%$, $SD = 35\%$) than in the Contrast Condition ($M = 45\%$, $SD = 39\%$). Children were significantly more likely than chance to select the object indicated by the previously accurate individual in the Preference Condition, $t(39) = 3.163$, $p < .05$, but were no different from chance in the Contrast Condition, $t(39) = -.813$, $p = .421$, n.s. See Fig. 2. All other main effects and interactions were non-significant.

In contrast to the mutual exclusivity bias that the preschoolers displayed in Experiment 1 involving word learning, the function learning in Experiment 2 did not result in a mutual exclusivity bias. Children's lack of a mutual exclusivity bias for functions is consistent with the view that preschool children, unlike older children and adults, do not suffer from 'functional fixedness'. That is, they do not appear to hold rigidly to the notion of one-to-one mappings between artifacts and functions (German & Defeyter, 2000; see also Defeyter & German, 2003; German & Barrett, 2005; Kelemen, 2004).

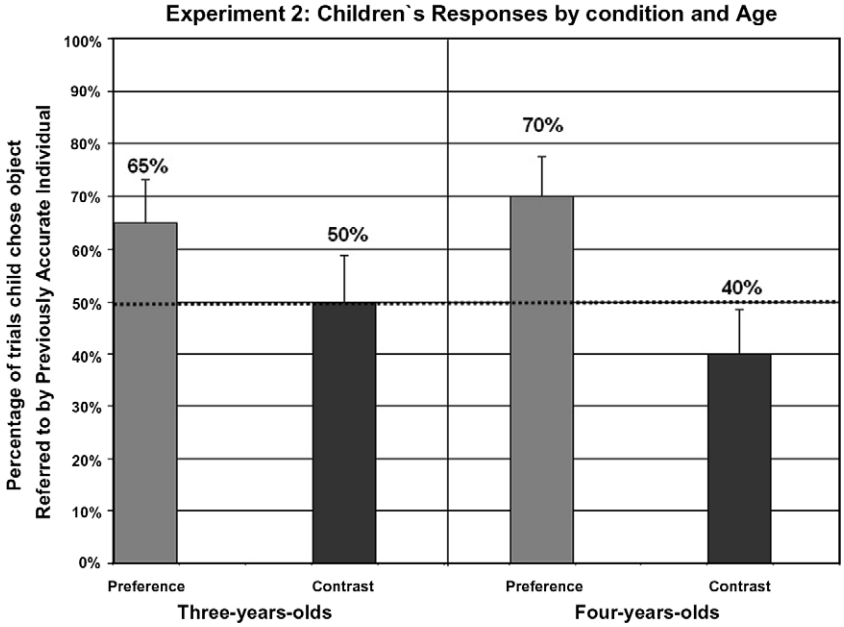

Fig. 2. Experiment 2: Children's responses by condition and age: Mean percentage of trials children chose the object referred to by the individual who was previously accurate at stating the typical functions for common objects.

On the other hand, as mentioned above, some researchers (e.g., Casler & Kelemen, 2005) have found evidence of mutual exclusivity for functions even in preschool children. In their studies Casler and Kelemen (2005) had an adult use one of two tools to perform a specific function (such as turning on a special light). When later asked to perform the same function, children showed a strong tendency to choose that tool themselves. Moreover, when asked which tool was needed to perform a different function (such as crushing crackers), children tended to choose the other toy. Why did a mutual exclusivity for functions emerge in their study and not in the present study?

In Casler and Kelemen (2005) the object functions were carefully demonstrated by the experimenter with explicit cues to intentional teaching (see Gergely & Csibra, 2004). This is very different from our current study in which the functions were stated verbally in response to the experimenter's query, by puppets resembling children, in a context in which conflicting information was provided and where the speakers prefaced their claims with "I think ...". For these reasons, the link between object and function was likely stronger in Casler and Kelemen than in the present study (2005), and hence more likely to fuel a mutual exclusivity effect. Note also that even under the conditions present in Casler and Kelemen (2005) a mutual exclusivity effect for functions is somewhat fragile: 4- and 5-year-olds were at chance in Study 1, and 2- and 3-year-olds were at chance in Study 2 the day of test, though they did show an effect after a 1–3 day delay.

In sum, the data from Experiment 2 suggests that children spontaneously keep track of individuals' prior history with regard to object functions and prefer to learn about the functions for new objects from the individual with the best track record of describing the typical functions for common objects. Unlike Experiment 1 we did not find a mutual exclusivity effect in the Contrast Condition. That is, when the experimenter asked for an object that could perform a different function than the function the speakers had provided children did not tend to choose the object referred to by the previously inaccurate individual. Nonetheless, there was not a significant bias favoring the object referred to by the previously *accurate* individual, thus, this condition serves to rule out more simplistic explanations for the findings in the Preference Condition – for instance, children are not simply choosing whatever object was referred to by the previously accurate individual.

4. General discussion

Our results revealed that 3- and 4-year-olds spontaneously keep track of others' history of being accurate versus inaccurate. They are more likely to learn new words (Experiment 1) and new object functions (Experiment 2) from someone who has been accurate in the past than from someone who showed signs of incompetence (in this case by repeatedly being inaccurate about the words for, or typical functions of, common objects).

Experiment 1 replicated Koenig et al. (2004) previous finding that children prefer to learn new words from someone with a history of being accurate about words over someone with a history of being inaccurate about words. Importantly, these findings hold even when children are not primed to think about the speaker's past performance, and when their word learning is put to a more robust test by capitalizing on the mutual exclusivity bias. 3- and 4-year-old children were able to utilize the new word they had just learned to infer the referent of a completely novel word based on children's tendency to treat words as mutually exclusive.

Experiment 2 provided the first evidence that children keep track of a person's history of being accurate or inaccurate in a domain other than word learning. When learning about object functions children showed a preference to favor someone who was previously accurate about the typical functions for common objects over someone who was previously inaccurate about the typical functions for objects. However unlike children's tendency to apply the principle of mutual exclusivity to the newly learned words in Experiment 1, children did not show a mutual exclusivity bias for the newly learned functions in Experiment 2, suggesting that a mutual exclusivity bias is more robust for words than for functions.

What remains somewhat unclear from this research, however, is precisely how children are reasoning about others' prior behavior. There are two quite different interpretations that one can take when considering these results. One interpretation is to frame this research as bearing on children's mental state understanding, (e.g., what children think about the knowledge of others). From this interpretation, our findings would be an extension of previous research on the development and use

of 'theory of mind' in the course of children's learning. For example, somewhat older children than those tested in the present study appreciate that adults tend to know more than they do (Taylor, Cartwrigth, & Bowden, 1991) and that different adults have knowledge and expertise in different areas (Danovitch & Keil, 2004; Lutz & Keil, 2002). They also can determine the most reliable source of information based on whether a person has had the right kind of perceptual access to the information (see Robinson, 2000 for a review), and whether that person has a vested interest in an outcome that may make them less objective (Mills & Keil, 2005).

This is the perspective taken by Koenig and Harris (2005), who introduce their studies by noting the existence of a considerable body of research concerning children's appreciation of how differences in perceptual access can lead to temporary differences in knowledge (e.g., John looks into a container and Mary does not; which person knows the container's contents?; Pratt & Bryant, 1990) and then noting that there has been little work to date that bears on the related question of "children's attribution of knowledge as a stable, person-dependent trait" (p. 1261).

We resonate with this perspective; our own motivation for pursuing this line of research was similar. But this sort of 'mentalistic' account of children's capacities could be mistaken. Successful performance on such learning tasks need not entail any theory of mind capacities. An alternative interpretation is that children's responses are based solely on generalizations about the speakers' *output*, without making any assumptions about the speaker's underlying mental states. Under this alternative, the child's responses might stem from inductive reasoning along the lines of: Speaker A produced 'good output' in the past; Speaker B produced 'bad output' in the past; hence if I want 'good output' I should go with Speaker A. This sort of inference requires no trait attribution, no inferences about epistemic states, no 'theory of mind' – just observation of behavior and learning by induction. To put it differently, children (and adults, for that matter) might make inferences about the accuracy of speakers in the same general way that we make inferences about the accuracy of non-mentalistic objects such as thermometers, scales, or clocks. If Clock A got the time right in the past and Clock B got it wrong, people will tend to look at Clock A in the future, without necessarily engaging in any reasoning about the internal aspects of the clocks.

What evidence would bear on the question of whether or not children are basing their inferences on mental state attribution? Although very young children may lack the more sophisticated understanding of the mind that adults or older children have, even very young children can utilize some aspects of the speaker's mental states (e.g., goals, intentions, desires, knowledge states) to facilitate learning (e.g., Baldwin, 1991, 1993; Diesendruck, Markson, Akhtar, & Reudor, 2004; Jaswal, 2004; Saylor & Troseth, 2006; Tomasello, Strosberg, & Akhtar, 1996). For instance, 2-year-olds can infer the precise referent of a new word based on their understanding of what the speaker could or could not know (e.g., Birch & Bloom, 2002). Are the 3- and 4-year-olds in the present studies making similar inferences about what the speakers are likely to know?

Possibly. As noted previously, even 16-month-olds detect when people provide incorrect labels for common objects (Koenig & Echols, 2003). What is particularly interesting is that these infants are doing more than merely responding to good out-

put versus bad output. They looked longer at someone who gave incorrect object labels, but they did not look longer at an audio-speaker when it provided incorrect labels; nor when a human speaker provided incorrect labels for objects she could not see. Indeed, the infants looked longer at the human speaker when she provided the *correct* labels for objects she could not see. This suggests that even babies are not merely 'output-minded' and raises the possibility that they can distinguish between an error that indicates ignorance versus an honest mistake.

The present research was not designed to differentiate between mentalistic and non-mentalistic explanations of the findings, so although we favor the former interpretation, we caution against making assumptions about the mechanisms underlying children's abilities on these types of tasks (see also Brosseau-Liard & Birch, 2007; Nurmsoo & Robinson, in press; Nurmsoo & Robinson, under review, for further research on this issue). What the present research does reveal is that 3- and 4-year-old children spontaneously keep track of others' histories of being accurate or inaccurate and use that information to facilitate subsequent learning. They prefer to learn words from someone with a good track record of word labeling over someone with a poor track record of word labeling, and they prefer to learn functions from someone with a good track record of function knowledge over someone with a poor track record of function knowledge.

In sum, these findings indicate that children at this age are sensitive to others' mistakes, are able to keep tabs on their social partners' recent history of being accurate or inaccurate, hold that person-specific information in memory, and possess at least an implicit appreciation that an individual's prior competence can be a useful indicator of that person's future competence. Importantly, this research shows that children's early sensitivity to others' mistakes is not specific to mistakes in language and it shows that not only *can* children use a person's prior accuracy to decide who to learn from in the future, but they spontaneously do so without any prompting. They appear intrinsically motivated to monitor and track their social partners' credibility to facilitate subsequent learning.

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