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The effect of a tactile-to-visual shift on young children's tendency to map novel labels onto novel objects

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ABSTRACT

When taught a label for an object and then asked whether an exemplar of that object or a novel object is the referent of a novel label, children favor the novel object. Preschool-aged children tend not to show this so-called disambiguation effect, however, when the test objects are presented in a different sense modality than the original object. The current experiments used a touch-to-vision paradigm to test two explanations for this unexpected pattern. Experiment 1 asked whether children might fail to retrieve the original label and found that additional label training benefitted 3-year-olds but not 4-year-olds. Experiments 2 and 3 asked whether children's reaction to discovering the cross-modal match might interfere with how they process the request for the novel label and found that being allowed to share their discovery of the match benefitted 4-year-olds but not 3-year-olds. These findings support the proposal that the chief obstacle to cross-modal disambiguation changes during early childhood from difficulty in retrieving the known label to disruption caused by the discovery of the cross-modal match.

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Introduction

From an early age, children show adaptive biases in their interpretation of novel words. For example, if taught a label for an object and then tested for whether they think this object or a novel object is the referent of a novel label, they favor the novel object (de Marchena, Eigsti, Worek, Ono, & Snedeker, 2011; Diesendruck & Markson, 2001; Scofield & Behrend, 2007; Suanda & Namy, 2013; Xu, Cote, & Baker, 2005). This result is one example of the *disambiguation effect* (Merriman & Bowman, 1989), or the tendency for children to map novel labels onto novel objects rather than objects that have known labels. When the testing paradigm is administered within the visual modality, as is typical, the disambiguation effect is both highly robust and reliable.

However, children tend not to show this effect when the testing paradigm is administered across different sensory modalities. On each of four trials, Scofield, Hernandez-Reif, and Keith (2009) taught 2- to 5-year-olds a label for an object (e.g., "zav") that was presented either tactually (Experiment 1) or visually (Experiment 2). At test, children were presented with both an exemplar of this object and a novel distractor object in the opposite sense modality. On some trials, children were asked for the referent of the originally trained label (e.g., "Which one is a zav?") In response, 3-, 4-, and 5-year-olds readily chose the exemplar. On other trials, children were asked for the referent of a novel label (e.g., "Which one is a tigg?"). Surprisingly, children on these trials did not respond by choosing the novel object (i.e., they did not show the disambiguation effect). Instead, they chose the exemplar. This result constituted a rare instance in which preschool-aged children failed to show the disambiguation effect.

According to two leading accounts, successful disambiguation requires children to realize that they know the name of one of the objects and then shift focus to the other object. For the *mutual exclusivity* account (Markman & Wachtel, 1988; Merriman & Marazita, 1995), knowing the name of an object allows children to eliminate that object as a candidate for the novel label because one object does not usually have two different names. For the *pragmatic contrast* account (Clark, 1990; Diesendruck & Markson, 2001; Gathercole, 1989), knowing the name of an object allows children to eliminate that object as a candidate for the novel label because speakers do not usually use a novel label to refer to a known object. With one object eliminated, children shift focus to the other (novel) object.

For both accounts, retrieving a label for one of the objects leads children to map the novel label to the other object. One hypothesis, then, is that children have more trouble with cross-modal disambiguation because the modality shift disrupts their ability to retrieve a label for the original object. This hypothesis is based on changes in the way that an object is decoded when it is encountered in a new sense modality. The salience of certain features may change. For example, a shift from vision to touch might lower the salience of an object's color but raise the salience of its texture (Bushnell & Baxt, 1999; Kalagher & Jones, 2011; Lederman & Klatzky, 1987).

A second hypothesis is that children's reaction to discovering that one of the objects in the new sense modality matches the training object disrupts their tendency to focus on the novel object. Their interest in this discovery could cause them to stay focused on the matching object rather than shift to the novel object. Surprise or excitement over the discovery might also support continuing to focus on the matching object. A common consequence of surprise is disruption of ongoing processes and reallocation of resources to the surprise-inducing stimulus (Reisenzein, 2000; Roseman, 2013), which in this case would be the cross-modal match.

Wall, Merriman, and Scofield (2015) evaluated these hypotheses using the vision-to-touch cross-modal paradigm where label training occurred in the visual modality but testing occurred in the tactile modality. Experiment 1 tested the failed label retrieval hypothesis with 3- and 4-year-olds. The procedure closely followed that of Scofield et al. (2009, Experiment 2) with one exception: To help increase the likelihood of retrieval, children received additional label training. Results showed that disambiguation improved compared with Scofield et al. but that neither age group disambiguated at levels above chance. Experiment 2 tested both hypotheses. Here Wall et al. inserted a discovery prompt immediately after the modality shift but before testing. In the *labeled match* condition, children were asked to select the referent of the trained label. In the *unlabeled match* condition, children were asked simply to select the object that was "like" the training object. Children chose the cross-modal match in response to both of these prompts. Children then proceeded to testing and were asked to select the referent of the novel label. In the labeled match condition, where the trained label was provided, both 3- and 4-year-olds showed the disambiguation effect. However, in the unlabeled match condition, where the trained label was not provided, only 4-year-olds showed the effect.

These results suggest that 3- and 4-year-olds might face different obstacles to cross-modal disambiguation (Wall et al., 2015), with 4-year-olds possibly facing discovery-based interference. In both conditions of Experiment 2, 4-year-olds discovered the cross-modal match but were immediately allowed to express surprise at their discovery and satisfy any need to communicate about it. With the sources of interference removed, they readily carried out the processes required for disambiguating. To do this in the unlabeled match condition indicates that 4-year-olds successfully retrieved the label for the match and then eliminated the match as a candidate for the novel label. These results support the conclusion that discovery-based interference, and not failed label retrieval, accounts for 4-year-olds' tendency not to show the cross-modal disambiguation effect.

In contrast, 3-year-olds' obstacle may be label retrieval failure. When the label was not provided, as in the unlabeled match condition, 3-year-olds did not show the disambiguation effect. When the label was provided, as in the labeled match condition, 3-year-olds did show the effect. Note that although these results implicate failed label retrieval as being at least part of the reason why 3-year-olds tend not to show the cross-modal disambiguation effect, it is possible that discovery-based interference also affects this age group. In the only condition where they showed the disambiguation effect—the labeled match condition—they not only first retrieved the label for the matching object but also satisfied any putative desire or expectation to communicate about this object before they were asked to decide which object was the referent of the novel label.

Wall and Merriman (2015) directly assessed children's expectations in the cross-modal disambiguation paradigm. The participants, 3- and 4-year-olds, learned a label for a visual object and then examined a pair of tactile objects that consisted of the cross-modal match and a novel object. The experimenter then asked, "What do you think I'm going to ask? Which one will I ask you to pick? Can you hand me one?" If the claim that only 4-year-olds experience discovery-based interference is valid, then one might expect this age group to show a stronger tendency than 3-year-olds to focus on the cross-modal match when answering these questions. This prediction was supported. In fact, only the older group mentioned or selected the cross-modal match more often than the novel object in response to these questions.

The goal of the current investigation was to examine the role of discovery-based interference and failed label retrieval in a touch-to-vision version of the cross-modal paradigm. By doing so, we hoped to shed light on processes involved in novel label mapping and in cross-modal sensory integration. Although the investigations by Wall and colleagues obtained valuable information about how these phenomena affect preschoolers in the vision-to-touch paradigm (Wall & Merriman, 2015; Wall et al., 2015), the roles of retrieval and discovery still need to be clarified for 3-year-olds. There are good reasons to question whether results would be the same if the modality shift were reversed.

Children's performance in the touch-to-vision and vision-to-touch versions of the test may be asymmetrical. They may find it easier to spontaneously retrieve the trained label for the cross-modal match at test in the touch-to-vision version because they have more experience in encoding visual objects. Furthermore, classic work in sensory integration suggests an advantage for visual learning over tactile learning of objects in children, including in cross-modal tasks (Blank & Bridger, 1964; Milner & Bryant, 1970; Rose, Blank, & Bridger, 1972; Rudel & Teuber, 1964). Even for adults, the form or shape of an object can be encoded more quickly and automatically via vision than via touch (Bliss & Hämäläinen, 2005: Butter & Björklund, 1976). If children expend more working memory resources encoding an object by touch than by vision, this difference is likely to have a greater impact at test than during training. During training, children may well have sufficient working memory to encode a single object regardless of its modality. In addition, even if children find it more difficult to learn a label for a tactile object than for a visual object during training, our procedure requires them to show that they can recall the label for the training object before proceeding to the test. At test, they must encode two objects in addition to carrying out all the other processes involved in deciding which object is the referent of a novel label. Some may have sufficient resources to execute all these processes successfully for two visual objects but not for two tactile objects. Furthermore, older preschoolers may surpass their younger counterparts when performing complex tasks due to better command of working memory (Garon, Bryson, & Smith, 2008).

Experiment 1

On each of four trials, 3- and 4-year-olds were taught a label for a novel training object that they could touch but not see. Children needed to demonstrate successful recall of this label before proceeding to the test phase of the experiment. During the test phase, while still holding the training object in their hands (but not seeing it), children were shown two test objects that they were not permitted to touch. One of these was an exemplar of the training object (i.e., its cross-modal match), and the other one was a novel distractor object. On some trials, children were asked to select the referent of the trained label. On other trials, children were asked to select the referent of a novel label. These were the critical trials.

Method

Participants

In total, 22 3-year-olds (M = 43 months, range = 37–47; 8 boys) and 22 4-year-olds (M = 53 months, range = 48–59; 12 boys) participated. The children were recruited from preschools near a major state university in the southeastern region of the United States. Most were White and middle class, and all spoke only English. Only children who assented to the procedures, and for whom parental consent had been obtained, participated in the experiment. Children received a sticker for participation.

Materials and procedure

The children completed a 10- to 15-min session in a quiet room at their preschool. For the label training and test trials, a large wooden box (painted white) measuring 16 in. deep × 17 in. wide × 8.5 in. high was used (see Fig. 1). The box was open on one side so that the training object for each trial could be transferred in and out of the child's hands by the experimenter. The opposite side of the box had two round holes cut into it. These were 3 in. in diameter and had cotton sleeves attached. The holes were large enough to accommodate children's arms when reaching into the box, and the sleeves prevented children from peeking inside the box while not limiting their ability to touch and manipulate the training object. The top of the box was flat and served as a stage for the pair of test objects. The box was also bottomless such that when it sat on a table there was no lower side.

Fig. 1. Image of the box and sample novel objects.

Children completed four trials. Each trial involved a different set of three novel objects (a novel training object, an exemplar that matched it, and a novel distractor). The set objects sometimes differed by material (e.g., plastic, rubber, metal) or texture (e.g., smooth, ribbed, fuzzy), but they all were similar in weight (40–100 g) and overall size (between 1.5 and 2.5 in. at the widest point), and they were unknown to children and easy to manipulate (see Fig. 1). Six novel labels (e.g., *zav, cobe, ferp, jeet, hust,* and *lide*) were used to name the training object and when requesting an object at test. Use of the words was counterbalanced across trials so that the same word was never used in multiple trials with the same child and each word could potentially serve as the label of the training object or as the label used on disambiguation trials.

Warm-up task

The experimenter began each session by introducing the children to the box. To ensure children's comfort, the experimenter placed a familiar object in the box (e.g., a ball or shoe) and invited the children to reach their hands inside to describe and identify the object. Children were asked questions such as "Is what you are feeling hard or soft?" and "[Is it] big or small?" and finally "What is it?" If children were reluctant to place their hands in the box initially, the experimenter turned the box over, explained that it was empty inside, and invited the children to place a sticker on the interior of the box. The experimenter then reoriented the box and asked the children to reach inside and find their sticker. Once these children were comfortable with the box, the experimenter returned to introducing and inquiring about the familiar object. Once children had answered all of the questions about the object in the box, the experimenter removed it from the box and showed it to the children.

Label training and recall phases

Following the warm-up task, children were invited to play a game where they would learn names of things. The game involved four trials. Each trial involved three phases: the label training phase, the recall phase, and the cross-modal test phase. In the label training phase, children were asked to reach their hands through the sleeves and into the box and were reminded not to peek inside. The experimenter then put a novel training object in their hands and labeled it three times (e.g., "This is a zav. It's a zav. You're feeling a zav."). Children were asked to repeat the novel label aloud, and then the training object was removed from their grasp. Before moving to the recall phase, children completed a brief distraction task. The experimenter held up some fingers and asked the children to count them. The experimenter then repeated this request for a different number of fingers. This counting task was intended to clear the children's sensory register of the trained label. During the recall phase, the experimenter placed the training object back in the children's hands and asked them to recall its name. If children did not recall the trained label, the experimenter repeated the entire procedure that had been followed up to this point (i.e., the training phase, the distraction, and the recall phase). Once the label recall phase was passed, or once the procedure had been repeated three additional times, the children advanced to the cross-modal test phase.

Cross-modal test phase

For the cross-modal test phase, children kept their arms in the box and continued to hold the training object while the experimenter placed a pair of test objects on top of the box. One of these objects was an exemplar of the training object (i.e., its cross-modal match, another "zav"), whereas the other object was a novel distractor. On two of the four trials, the experimenter then asked the children to pick the object that was a referent of the trained label (e.g., "Do you know what a zav is? One of these is a zav. Which one is the zav?") On the other two trials, the experimenter asked them to pick the object that was the referent of a novel label (e.g., "Do you know what a zav is? One of these is a tigg. Which one is the tigg?") Children indicated their selection by tapping underneath the selected object or by pulling out their hand and pointing to the selected object. Neutral feedback was provided after each selection (e.g., "Okay"). For half of the children in each age group, the referent of the trained label was requested on the first and fourth trials. For the remaining half, it was requested on the second and third trials.

Results

Recall of the trained label

For the training phase, the average number of training rounds for 3-year-olds (M = 2.00, SD = 0.70) did not differ from the average number for 4-year-olds (M = 1.73, SD = 0.53), $t(42)$ = 1.46, p = .15. Overall, children recalled the trained label after one round of training on 43% of the trials (73/176).

Cross-modal tests

During the cross-modal test phase, 3- and 4-year-olds were asked to choose the referent of a trained label (two trials) or the referent of a novel label (two trials). Table 1 presents a summary of their scores (0, 1, or 2 correct). For the trained labels, nearly every child in both age groups (19/22 and 21/22) correctly chose the exemplar on both trials. For the novel labels, which were the critical disambiguation trials, 3-year-olds correctly selected the novel object at above chance levels, $\chi^2(1, N = 22) = 11.00$, p = .004, whereas 4-year-olds did not, $\chi^2(1, N = 22) = 3.04$, p = .21. The two ages did not differ in the distribution of their responses, $\chi^2(2, N = 44) = 1.12$, p = .57.

Discussion

Experiment 1 found evidence for the cross-modal disambiguation effect in 3-year-olds—the first study to do so. The only other study to use the touch-to-vision paradigm to explore novel word learning (Scofield et al., 2009, Study 1; but see Kalagher & Jones, 2011, for use of the touch-to-vision paradigm with familiar words) found that preschoolers did not disambiguate. In fact, Scofield et al. (2009) found the reverse effect; children favored the exemplar of the trained label over the novel object. This change in performance can be attributed to two additions in Experiment 1: a recall test and extra training opportunities. Before the test phase was administered, children needed to successfully recall the trained label. Children who failed to do so on the first try received additional rounds of training until recall was successful. Because recall on the first try was rare, children in Experiment 1 often received additional training. Scofield et al. did not test recall and did not provide additional training. The differences between the two studies suggest that disambiguation in Scofield et al. likely suffered due to poor retrieval of the trained label.

Wall et al. (2015) also included a recall test and additional training opportunities in their vision-to-touch version of the cross-modal paradigm. But these additions did not lead children to reliably disambiguate. When the current findings are considered together with those of Wall et al., they support the conclusion that the chief obstacle to the cross-modal disambiguation effect changes over the preschool years. Whereas 3-year-olds fail because they do not spontaneously retrieve the trained label for the cross-modal match, 4-year-olds fail because their reaction to discovering the cross-modal match interferes with the processes that they usually carry out when determining the referent of a novel label. Because of this interference, 4-year-olds do not show the effect in either the touch-to-vision or vision-to-touch paradigm. In contrast, because 3-year-olds do not experience such interference, and because label retrieval occurs more readily in the touch-to-vision paradigm than in the vision-to-touch paradigm, 3-year-olds show the disambiguation effect only in the touch-to-vision paradigm.

Table 1
Distribution of scores (number correct) in the cross-modal tests.

		Experiment 1		Experiment 2		Experiment 3	
Age	Score	Trained label	Novel label	Trained label	Novel label	Trained label	Novel label
3 years	0	1	5	2	1	–	–
	1	2	5	5	4	–	–
	2	19	12	15	17	–	–
4 years	0	0	5	5	2	0	0
	1	1	8	7	6	8	4
	2	21	9	15	19	9	13

Experiment 2

Experiment 2 was similar to Experiment 1 except for the addition of an unlabeled match request. At the beginning of the cross-modal test phase, 3- and 4-year-olds were asked to select the object that was "like" the training object. Including this discovery prompt was intended to reduce or eliminate the potential for discovery-based interference. Children were expected to respond to the unlabeled match request correctly by selecting the exemplar of the trained label, thereby satisfying any need to share their discovery. Because 4-year-olds were hypothesized to be more prone to discovery-based interference than 3-year-olds, 4-year-olds were expected to benefit more than 3-year-olds from the change in procedure.

Method

Participants

In total, 22 3-year-olds (M = 43 months, range = 36–47; 10 boys) and 27 4-year-olds (M = 53 months, range = 48–59; 10 boys) participated in Experiment 2. Sample demographics were similar to those in Experiment 1, and participating children again received a sticker.

Materials and procedure

The materials and procedure in Experiment 2 were the same as those in Experiment 1 except for the insertion of the unlabeled match question at the beginning of the cross-modal test phase of each trial. Before children were asked to decide which object was a referent of the trained label or novel label, they were asked which of the two test objects was like the training object (i.e., "Which one is like the one you're holding?").

Results

Recall of the trained label

The average number of training rounds that 3-year-olds received (M = 2.13, SD = 0.77) did not differ from the number that 4-year-olds received (M = 2.11, SD = 0.72), $t(47) = 0.07$, $p = .95$. Overall, children recalled the trained label after one round of training on 31% of the trials (60/196).

Cross-modal tests

In both age groups, children nearly always responded correctly when asked which test object was "like" the training object. Average frequency of correct response for the four trials was 3.73 (SD = 0.46) and 3.85 (SD = 0.36) in the 3- and 4-year-olds, respectively, t(39.67, equal variances not assumed) = 1.04, $p = .30$.

For the trained labels, a majority of children again correctly chose the exemplar on both trials, $\chi^2(2, N = 49) = 34.35$, $p < .0001$, and the distribution of scores did not differ by age (Fisher exact test, $p = .61$). See Table 1. However, there were fewer high scores in the current experiment than in Experiment 1 (Fisher exact test, $p = .003$). Whereas 91% answered correctly on each of the two trials in Experiment 1, only 61% did so in the current experiment.

For the novel label trials, both 3-year-olds, $\chi^2(1, N = 22) = 32.18$, $p < .01$, and 4-year-olds, $\chi^2(1, N = 27) = 29.74$, $p < .01$, correctly selected the novel object at above chance levels. The two ages did not differ in the distribution of their responses, $\chi^2(2, N = 49) = 0.34$, $p = .85$. Across the two experiments, the distribution of scores for novel label trials differed significantly (Fisher exact test, $p = .021$). Whereas 48% answered correctly on both of the novel label trials in Experiment 1, 73% did so in the current experiment. See Table 1. Most noteworthy was the change in performance for 4-year-olds. The proportion of 4-year-olds who answered correctly on both trials was significantly higher in the current experiment (19 of 27) than in Experiment 1 (9 of 22) (Fisher exact test, $p = .048$).

Discussion

Experiment 2 found evidence for the cross-modal disambiguation effect in 3- and 4-year-olds. As in Wall et al. (2015), the critical addition in Experiment 2 was a discovery prompt; children were allowed to identify the test object that was "like" the training object before they heard the novel label. In both studies, the inclusion of this prompt boosted the performance of 4-year-olds (allowing them to show the cross-modal disambiguation effect) but did not boost the performance of 3-year-olds. This pattern of results is consistent with two of our claims. First, giving children an opportunity to share their discovery of the cross-modal match reduces or eliminates discovery-based interference. Second, 4-year-olds benefit uniquely from this opportunity because they seem more likely than 3-year-olds to experience the interference.

It is possible, however, that an alternative account explains the performance of 4-year-olds in Experiment 2. When asked to choose between two objects and then immediately asked to choose between them again, children might just have a general tendency to switch choices. One might even interpret the pragmatic contrast account (Clark, 1990; Diesendruck & Markson, 2001; Gathercole, 1989) as supporting this bias. For example, if children assumed that the two different requests referred to two different things, then their selection of the novel object could have been more about this bias than about discovery.

There is some evidence that response switching may have occurred. When asked for the referent of the trained label, children in Experiment 2 chose the cross-modal match less frequently than children in Experiment 1. Having already selected the match during discovery, perhaps these children were biased to switch to the other object. On the other hand, most children did not err on these trials in either experiment, and Experiment 2 included more time and activity between recall and test than Experiment 1. Whether cross-modal disambiguation in 4-year-olds is best explained by response switching or by a reduction in discovery-based interference was the focus of Experiment 3.

Experiment 3

Experiment 3 differed from Experiment 2 in two respects. First, to block the possible role of response switching, Experiment 3 included two distractor questions between discovery and the test phase. Specifically, children were asked "Are these for mommies and daddies or for kids?" and "Which one do you like better?" Separating these events solved two potential issues from Experiment 2. First, it removed the possibility that disambiguation was simply a result of response switching between the two events. It also negated any possible pragmatic expectation that children may have had about which object the experimenter intended to refer to. Second, only 4-year-olds were assessed in Experiment 3. Because the results of Experiment 1 showed that cross-modal disambiguation in 3-year-olds was not due to response switching, there was no need to include them in this experiment. The 4-year-olds were predicted to continue to show the disambiguation effect even with response switching controlled.

Method

Participants

In total, 17 4-year-olds (M = 55 months, range = 48–59; 10 boys) participated in Experiment 3. Sample demographics were similar to those in earlier experiments, and participating children again received a sticker.

Materials and procedure

The materials and procedure in Experiment 3 were the same as those in Experiment 2 with one exception. After the unlabeled match question, but before the cross-modal tests, children were asked two control questions about the test objects: "Are these for mommies and daddies or for kids?" and "Which one do you like better?" The order of these questions was counterbalanced.

Results

Recall of the trained label

The average number of training rounds that the children received was 1.63 (SD = 0.77). Children recalled the trained label after one round of training on 41% of the trials (28/68).

Cross-modal tests

As in Experiment 2, 4-year-olds nearly always responded correctly to the unlabeled match question. The average frequency of correct response (max = 4) was 3.88 (SD = 0.33).

For the trained labels, as in earlier experiments, the majority of 4-year-olds chose correctly on each of the two trained label trials. Of the 17 participants in this experiment, 9 chose correctly on both trials (binomial probability < .025). (Chi-square analyses were not run because no child chose incorrectly on both trials.) The distribution of scores (0, 1, or 2) on the trained label trials was similar to that for 4-year-olds in Experiment 2 (Fisher exact test, p = .099) but differed from that for 4-year-olds in Experiment 1 (Fisher exact test, p = .005). In Experiment 1, 95% answered correctly on each of the two trials. In contrast, 53% and 55% did so in the current experiment and Experiment 2, respectively.

For novel label trials, 4-year-olds' performance was excellent. Of the 17 participants in this experiment, 13 chose correctly on both trials (binomial probability < .0001) and no child chose incorrectly on both trials. The distribution of scores (0, 1, or 2) on the novel label trials was similar to that for 4-year-olds in Experiment 2 (Fisher exact test, p = .74) but differed from that for 4-year-olds in Experiment 1 (Fisher exact test, p = .039). Whereas the percentage of 4-year-olds answering correctly on each of the two trials was 76% and 70% in the current experiment and Experiment 2, respectively, only 41% showed this pattern in Experiment 1.

Discussion

As in Experiment 2, 4-year-olds in Experiment 3 showed a robust cross-modal disambiguation effect. Importantly, this effect could not have been an artifact of a response-switching bias. After sharing their discovery of the match, 4-year-olds answered two distractor questions that reset their attentional focus to both objects. This left no reason to choose one object over the other based simply on previous choices. Also important, Experiment 3 still controlled for discovery-based interference in that children were allowed to satisfy any expectation or desire they had to talk about the cross-modal match. Replication of the cross-modal disambiguation effect across Experiments 2 and 3 provides further support for the claim that 4-year-olds' initial failure to disambiguate was due to discovery-based interference.

General discussion

Three experiments explored preschoolers' tendency to produce the disambiguation effect when it requires applying their label knowledge about a tactile object to a choice between visual objects. Scofield et al. (2009) previously found that children's usual tendency to map a novel label to a novel object was disrupted when learning and testing occurred across different sensory modalities. Wall et al. (2015) hypothesized two primary sources for the disruption: failed label retrieval and discovery-based interference. The latter occurred when older children discovered that one of the test objects was like the training object. Their desire to share this discovery with the experimenter took primacy over choosing the correct object. The other source of disruption occurred when younger children failed to retrieve the label that they were originally taught. Without this trained label, they were uncertain which of the test objects the novel label might denote. Wall et al. found that 3- and 4-year-olds' differential responses to various modifications in training and testing procedures in the vision-to-touch paradigm were consistent with the predictions of this developmental account.

Results from the current experiments provided further support for the account. The 3-year-olds' performance in Experiment 1 was consistent with the failed label retrieval hypothesis. In the only previous study to use the touch-to-vision test on novel word learning (Scofield et al., 2009, Study 1), children failed to show the cross-modal disambiguation effect. The critical difference between the two studies was that Experiment 1 required children to recall the trained label before testing. In Experiment 1, children frequently failed to retrieve the label after the first round of training, so they required additional rounds of training. On average, 3-year-olds in Experiment 1 required two rounds of training. Children in Scofield et al. were not required to recall the trained label prior to testing and so received only the initial round of training. Their subsequent failure to disambiguate likely was due to an inability to retrieve the trained label at test.

Despite the procedural changes, 4-year-olds in Experiment 1 did not show the cross-modal disambiguation effect, suggesting that their failure was not due to problems with retrieval. Instead, we hypothesize that their failure was due to discovery-based interference (Wall et al., 2015). We believe that when 4-year-olds are excited or surprised to discover that the training object matches a test object, they subsequently desire to communicate this discovery. We further believe that this desire interferes with disambiguation by pulling children's attention toward the match and away from the novel object. If so, then providing children with an opportunity to communicate the discovery might satisfy their desire and, thus, reduce any possible interference with their object choice. Experiments 2 and 3 provided exactly this opportunity by allowing children to identify the cross-modal match before testing. In response, 4-year-olds showed the cross-modal disambiguation effect in both experiments, including the unlabeled match conditions where simply identifying the one that was "like" the training object satisfied their desire. Performance in these experiments supports the possibility that discovery-based interference might help to explain previous failures given that prompting children to share their discovery led to successful disambiguation. Wall et al. (2015) found that such a discovery prompt had a similar effect on 4-year-olds in the vision-to-touch test. Thus, for this age group, discovery-based interference might not be limited to a particular direction of modality change. In neither the current investigation nor Wall et al. (2015) did 3-year-olds show a stronger disambiguation effect when the unlabeled match question was added to the procedure than when it was not, suggesting that 3-year-olds are not experiencing discovery-based interference.

The failed label retrieval and discovery-based interference hypotheses are potentially relevant to novel label mapping problems that do not involve a sensory modality shift. The disambiguation effect should be weaker in any situation where children's likelihood of retrieving the label for the "familiar" object is lower or their likelihood of considering this object to be a discovery is higher.

In support of this proposal for failed label retrieval, Grassmann, Schulze, and Tomasello (2015) found that children tended not to avoid mapping a novel label to a familiar kind of object when they had only receptive knowledge of the label for this object. That is, it was not sufficient for them to be able to recognize the label and pick out its exemplar; they also needed to be able to produce the label when asked to name an exemplar. The phenomenon of failed label retrieval may be relevant to the finding that the disambiguation effect tends to be positively correlated with children's age (Bion, Borovsky, & Fernald, 2013; Lewis & Frank, 2015; Merriman, Marazita, & Jarvis, 1995), vocabulary size (Lewis & Frank, 2015; Mervis & Bertrand, 1994), and ability to identify gaps in one's lexical knowledge (Merriman & Schuster, 1991; Wall et al., 2015). Efficiency in label retrieval, as measured by speed of naming familiar objects, has been found to be positively correlated with age and the ability to identify gaps in one's lexical knowledge in preschoolers (Lipowski & Merriman, 2011). See Wall et al. (2015) for suggestions of other kinds of variation in the strength of the disambiguation effect that may be explained by variation in children's likelihood of retrieving an object's known label.

Regarding the generality of the discovery-based interference hypothesis, Wall and Merriman (2015) demonstrated that an unexpected object match reduced the disambiguation effect in a situation that does not involve cross-modal transfer. Preschoolers were taught a label for a novel training object, which was then placed out of sight. The children were then asked to retrieve a small box from across the room. The experimenter opened the box to show that it contained a different novel object and, unexpectedly, another copy of the training object. When asked to indicate which one was a referent of a novel label, fewer children selected the novel object compared with those in a control group who had been led to expect to find the copy of the training object in the box.

Although there has been no research on discovery-based interference in other forms of language comprehension or problem solving, several studies have demonstrated that children appreciate the social significance of discovering a mutually known object or event in a new context. In some studies, even very young children have shown this appreciation. For example, in Liebal, Carpenter, and Tomasello (2010), 18-month-olds were shown two pictures of toys and spontaneously pointed toward whichever toy they and the accompanying adult had played with earlier (see also Liszkowski, Carpenter, & Tomasello, 2007; Moll, Richter, Carpenter, & Tomasello, 2008; Saylor & Ganea, 2007). Other studies have shown that an appreciation for the significance of some discoveries emerges later in childhood. In Liebal, Carpenter, and Tomasello (2013), an experimenter showed 3- and 5-year-olds an object that was a culturally well-known character (e.g., Santa Claus) and an object that was a new character created on the spot. When a new adult entered the room, showed signs of recognizing one of the objects, and then made an ambiguous request, only the 5-year-olds interpreted it as a request for the culturally well-known character. It may be that younger children appreciate the social significance of a mutually known object only when the object is encountered in the same form, or nearly the same form, as in a previous joint encounter with it. So only older children may expect an adult to take an interest in a novel Santa Claus doll or in an object that is encountered in a new sensory modality.

Finally, our findings shed some light on the nature of children's sensory integration processes. The main difference between the procedure of the current investigation and that of Wall et al. (2015) was the direction of the sensory modality shift. The 3-year-olds showed the disambiguation effect in our first two experiments, whereas the 3-year-olds in the corresponding conditions of Wall et al. did not. This contrast supports the claim that young children's likelihood of spontaneously retrieving a label for an object after a sensory modality shift depends on the direction of the shift. The likelihood is higher when the shift is from touch to vision than when it is from vision to touch, assuming equivalent levels of initial label mastery. This was true despite 3-year-olds needing more training to achieve mastery in the touch-to-vision paradigm of the current experiments than in the vision-to-touch paradigm of Wall et al. These findings makes sense given that the shape of an object can be encoded more quickly and effortlessly via vision than via touch (Bliss & Hämäläinen, 2005; Butter & Björklund, 1976) and that shape tends to be a reliable retrieval cue for object labels (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976; Smith, Jones, Landau, Gershkoff-Stowe, & Samuelson, 2002).

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.jecp.2018.03.003.

References

Bion, R., Borovsky, A., & Fernald, A. (2013). Fast mapping, slow learning: Disambiguation of novel word–object mappings in relation to vocabulary learning at 18, 24, and 30 months. *Cognition, 126*, 39–53.
Blank, M., & Bridger, W. H. (1964). Cross-modal transfer in nursery-school children. *Journal of Comparative and Physiological Psychology, 58*, 277–282.
Bliss, I., & Hämäläinen, H. (2005). Different working memory capacity in normal young adults for visual and tactile letter recognition task. *Scandinavian Journal of Psychology, 46*, 247–251.
Bushnell, E. W., & Baxt, C. (1999). Children's haptic and cross-modal recognition with familiar and unfamiliar objects. *Journal of Experimental Psychology, 25*, 1867–1881.
Butter, E. J., & Björklund, D. F. (1976). Are two hands better than one? Assessing the information acquired from one- and two-handed haptic exploration of random forms. *Perceptual and Motor Skills, 43*, 115–120.
Clark, E. V. (1990). On the pragmatics of contrast. *Journal of Child Language, 17*, 417–431.
de Marchena, A., Eigsti, I. M., Worek, A., Ono, K. E., & Snedeker, J. (2011). Mutual exclusivity in autism spectrum disorders: Testing the pragmatic hypothesis. *Cognition, 119*, 96–113.
Diesendruck, G., & Markson, L. (2001). Children's avoidance of lexical overlap: A pragmatic account. *Developmental Psychology, 37*, 630–641.
Garon, N., Bryson, S. E., & Smith, I. E. (2008). Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin, 134*, 31–60.
Gathercole, V. C. (1989). Contrast: A semantic constraint? *Journal of Child Language, 16*, 685–702.
Grassmann, S., Schulze, C., & Tomasello, M. (2015). Children's level of word knowledge predicts their exclusion of familiar objects as referents of novel words. *Frontiers in Psychology, 6*. https://doi.org/10.3389/fpsyg.2015.01200.
Kalagher, H., & Jones, S. S. (2011). Developmental change in young children's use of haptic information in a visual task: The role of hand movements. *Journal of Experimental Child Psychology, 108*, 293–307.
Lederman, S. J., & Klatzky, R. L. (1987). Hand movements: A window into haptic object recognition. *Cognitive Psychology, 19*, 342–368.
Lewis, M., & Frank, M. C. (2015, March). *A meta-analytic approach to understanding the disambiguation effect*. Poster presented at the 2015 biennial meeting of the Society for Research in Child Development, Philadelphia.

Liebal, K., Carpenter, M., & Tomasello, M. (2010). Infants' use of shared experience in declarative pointing. *Infancy, 15*, 545–556.
Liebal, K., Carpenter, M., & Tomasello, M. (2013). Young children's understanding of cultural common ground. *British Journal of Developmental Psychology, 31*, 88–96.
Lipowski, S. L., & Merriman, W. E. (2011). Knowledge judgments and object memory processes in early childhood: Support for the dual criterion account of object nameability judgment. *Journal of Cognition and Development, 12*, 481–501.
Liszkowski, U., Carpenter, M., & Tomasello, M. (2007). Pointing out new news, old news, and absent referents at 12 months of age. *Developmental science, 10*(2), F1–F7.
Markman, E. M., & Wachtel, G. F. (1988). Children's use of mutual exclusivity to constrain the meaning of words. *Cognitive Psychology, 20*, 121–157.
Merriman, W. E., & Bowman, L. L. (1989). The mutual exclusivity bias in children's word learning. *Monographs of the Society for Research in Child Development*, 54(3–4, Serial No. 220).
Merriman, W. E., & Marazita, J. M. (1995). The effect of hearing similar-sounding words on young 2-year-olds' disambiguation of novel noun reference. *Developmental Psychology, 31*, 973–984.
Merriman, W. E., Marazita, J., & Jarvis, L. (1995). Children's disposition to map new words onto new referents. In M. Tomasello & W. E. Merriman (Eds.), *Beyond names for things: Young children's acquisition of verbs* (pp. 147–184). Hillsdale, NJ: Lawrence Erlbaum.
Merriman, W. E., & Schuster, J. M. (1991). Young children's disambiguation of object name reference. *Child Development, 62*, 1288–1301.
Mervis, C. B., & Bertrand, J. (1994). Acquisition of the novel name–nameless category (N3C) principle. *Child Development, 65*, 1646–1662.
Milner, A. D., & Bryant, P. E. (1970). Cross-modal matching by young children. *Journal of Comparative and Physiological Psychology, 71*, 453–458.
Moll, H., Richter, N., Carpenter, M., & Tomasello, M. (2008). Fourteen-month-olds know what "We" have shared in a special way. *Infancy, 13*(1), 90–101.
Reisenzein, R. (2000). The subjective experience of surprise. In H. Bless & J. P. Forgas (Eds.), *The message within: The role of subjective experience in social cognition and behavior* (pp. 262–279). Philadelphia: Psychology Press.
Rosch, E., Mervis, C. B., Gray, W. D., Johnson, D. M., & Boyes-Braem, P. (1976). Basic objects in natural categories. *Cognitive Psychology, 8*, 382–439.
Rose, S. A., Blank, M. S., & Bridger, W. H. (1972). Intermodal and intramodal retention of visual and tactual information in young children. *Developmental Psychology, 3*, 482–486.
Roseman, I. J. (2013). Appraisal in the motion system: Coherence in strategies for coping. *Emotion Review, 5*, 141–149.
Rudel, R. G., & Teuber, H. (1964). Cross-modal transfer of shape discrimination by children. *Neuropsychologia, 2*, 1–8.
Saylor, M. M., & Ganea, P. (2007). Infants interpret ambiguous requests for absent objects. *Developmental Psychology, 43*, 696–704.
Scofield, J., & Behrend, D. A. (2007). Two-year-olds differentially disambiguate novel words and facts. *Journal of Child Language, 34*, 875–889.
Scofield, J., Hernandez-Reif, M., & Keith, A. B. (2009). Preschool children's multimodal word learning. *Journal of Cognition and Development, 10*, 306–333.
Smith, L. B., Jones, S. S., Landau, B., Gershkoff-Stowe, L., & Samuelson, L. (2002). Object name learning provides on-the-job training for attention. *Psychological Science, 13*, 13–19.
Suanda, S. H., & Namy, L. L. (2013). Young word learners' interpretations of words and symbolic gestures within the context of ambiguous reference. *Child Development, 84*, 143–153.
Wall, J. L., & Merriman, W. E. (2015, March). *Can discourse expectations interfere with novel name mapping?* Poster presented at the biennial meeting of the Society for Research in Child Development, Philadelphia.
Wall, J., Merriman, W. E., & Scofield, J. (2015). Young children's disambiguation across the senses. *Cognitive Development, 35*, 163–177.
Xu, F., Cote, M., & Baker, A. (2005). Labeling guides object individuation in 12-month-old infants. *Psychological Science, 16*, 372–377.