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Can Language Do the Driving? The Effect of Linguistic Input on Infants' Categorization of Support Spatial Relations

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Abstract

Two experiments explored the effect of linguistic input on 18-month-olds' ability to form an abstract categorical representation of support. Infants were habituated to 4 support events (i.e., one object placed on another) and were tested with a novel support and a novel containment event. Infants formed an abstract category of support (i.e., looked significantly longer at the novel than familiar relation) when hearing the word "on" during habituation but not when viewing the events in silence (Experiment 1) or when hearing general phrases or a novel word (Experiment 2). Results indicate that a familiar word can facilitate infants' formation of an abstract spatial category, leading them to form a category that they do not form in the absence of the word.

On one side of the long-standing debate on the relation between thought and language has been the view that language can be a strong force in the development of particular concepts (Gopnik & Choi, 1995; Gopnik, Choi, & Baumberger, 1996; Vygotsky, 1962; Xu, 1999). This view has been particularly prominent in discussions of how children acquire the meanings expressed in relational terms, such as verbs and prepositions (Bowerman & Choi, 2001, 2003), with some researchers proposing that language may guide the development of relational concepts (e.g., Bowerman, 1996; Bowerman & Choi, 2001; Gentner & Boroditsky, 2001; Talmy, 1983). Language does guide how young children organize spatial events into language-specific semantic spatial categories (Choi & Bowerman, 1991), raising the question of whether experience with a particular spatial morpheme inspires children to form categories of spatial events that they may not otherwise form. However, a lack of experimental evidence has made the feasibility of this argument difficult to measure. Given that a specific word can facilitate infants' ability to form a category of objects (e.g., Balaban & Waxman, 1997; Waxman & Markow, 1995), it is possible that analogous results could be obtained with infants' ability to form an abstract categorical representation of a spatial relation. To explore this possibility, I examined the effect of linguistic input on infants' ability to form an abstract categorical representation of a spatial relation across two experiments.

One reason that language is thought to shape the spatial categories that young children form is the myriad ways in which languages organize spatial events, such as placing a cup on the table or a picture on the wall, into the same or many different semantic categories (Bowerman, 1989, 1996). Perhaps the most well-known example is the difference between English and Korean (Choi & Bowerman, 1991). English speakers linguistically divide events with containment and support relations into two distinct semantic categories: They label containment events as "in" and support events as "on." In contrast, Korean speakers

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linguistically organize these same spatial events based on whether two objects are made to fit with one another. Korean speakers label the action of placing one object in a tight-fit, or interlocking, relation as “kkita,” grouping dynamic tight-fit containment and tight-fit support events into a single semantic category. By 18 to 23 months, English- and Korean-learning toddlers already have begun to acquire these language-specific semantic categories (Choi, McDonough, Bowerman, & Mandler, 1999). English-learning toddlers comprehend “in” as referring to both tight-fit and loose-fit containment, whereas the Korean-learning toddlers comprehend “kkita” as referring to tight-fit containment and support. Hence, experience with a particular language leads toddlers to organize the same set of spatial events into different semantic categories.

It has been argued not only that children organize the same spatial events differently as a result of experience with a particular language but also that they potentially develop these categories because of their experience with particular spatial morphemes (Choi & Bowerman, 1991). For example, Bowerman and Choi (2001) argued that children learn to recognize less salient spatial events if these events are lexically marked (i.e., described linguistically). Hearing the same word across different contexts motivates young children to notice similarities across contexts that otherwise may not be readily apparent. Similarly, Gentner and Boroditsky (2001) proposed that a common label motivates children to attend to commonalities in their environment. However, they advanced this proposition further by arguing that the common label motivates children to make comparisons, which in turn facilitates the acquisition of the corresponding concept (Gentner & Namy, 1999).

Although there has been ample evidence to demonstrate that a novel word aids infants and children in forming a category of objects (e.g., Balaban & Waxman, 1997; Booth & Waxman, 2002; Gentner & Namy, 1999; Namy & Gentner, 2002), research has yet to investigate whether the same is true for infants’ ability to form a categorical representation of a spatial relation. Recently, however, Loewenstein and Gentner (in press) found that relational language facilitated preschool children’s performance in a spatial mapping task. Children were asked to find one object in a three-tiered box that was “in the same place” as a different box. Children found the task challenging, but they improved significantly when given familiar relational labels (e.g., “in,” “on,” or “under” or “top,” “middle,” or “bottom”). Loewenstein and Gentner proposed that the familiar labels focused children’s attention on the relational similarity across scenes and, consequently, aided them in abstracting the relational structure. Thus, relational language facilitated preschoolers’ ability to attend to and abstract relational information. One question these findings raise is whether the same effect could be obtained with infants, particularly those beginning to comprehend spatial language.

Although relational language facilitates children’s abstraction of relational information, language is not a necessary precursor in the development of these concepts. Well before they begin to comprehend language, preverbal infants can form abstract categorical representations of relational information. For example, when familiarized to different objects in a particular spatial relation and then tested with the familiar relation and an unfamiliar relation, each depicted by novel objects, infants look significantly longer at the unfamiliar than familiar relation. That is, infants discriminate between the familiar and unfamiliar relation independent of the specific objects that comprise the relations and consequently demonstrate the ability to form an abstract categorical representation of the relation. By 6 months, infants can form an abstract categorical representation of “above” versus “below” (Quinn, Cummins, Kase, Martin, & Weisman, 1996) and containment (Casasola, Cohen, & Chiarello, 2003). By 9 months, they can form an abstract spatial category of the relation “between” (Quinn, Adams, Kennedy, Shettler, & Wasnik, 2003). Hence, prior to the time that they begin to comprehend linguistic labels for these events, infants can form abstract representations of several different spatial relations.

This ability also extends to spatial relations that are not lexically marked in an infant's language. McDonough, Choi, and Mandler (2003) found that both English- and Korean-learning infants of 9, 11, and 14 months form a category of tight-fit containment action events, responding to tight-fit containment as distinct from loose-fit containment action events, and vice versa. However, infants do not form abstract categorical representations of all types of spatial relations. Casasola and Cohen (2002) found that 10- and 18-month-old infants provided no evidence of grouping tight-fit support and loose-fit support into a single abstract spatial category, one that would be consistent with the English semantic category of "on." Likewise, infants did not demonstrate the ability to group tight-fit containment and tight-fit support into a single spatial category, consistent with the Korean semantic category of "kkita." In contrast, infants could group tight-fit and loose-fit containment events into a single abstract spatial category, consistent with the English semantic category of "in." Thus, infants can form some abstract spatial categories (i.e., containment) but not others (i.e., support, tight-fit), suggesting that some spatial categories may be more difficult to learn.

Hence, infants can combine different types of containment events (e.g., tight-fit vs. loose-fit) into a spatial category as needed for the semantic categories of their language, whether this grouping entails responding to tight-fit containment as distinct from loose-fit containment (McDonough et al., 2003) or responding to both types of containment events as equivalent (Casasola & Cohen, 2002). However, infants do not demonstrate the same flexibility with support or tight-fit spatial events. Infants' difficulty in forming these spatial categories may arise because they do not recognize the common support relation across the tight-fit and loose-fit examples of support or the common tight-fit relation across the containment and support examples of tight-fit. Consequently, infants are unable to abstract the relation to form the spatial category. One possibility, however, is that language may provide the necessary scaffolding to direct infants' attention to the common spatial relation and, consequently, aid them in forming the abstract spatial category (Bowerman & Choi, 2001; Gentner & Namy, 1999).

In the present experiments, I explored this possibility by testing 18-month-old infants on their ability to form an abstract categorical representation of a spatial relation in the presence versus absence of linguistic input. Like the preschool children tested by Loewenstein and Gentner (in press), 18-month-old infants may be able to use their familiarity with a particular spatial word to recognize and categorize a common relation presented across different pairs of objects. Given 18-month-old infants' difficulty with forming a spatial category of support (Casasola & Cohen, 2002), in the present experiments I examined whether adding the spatial word "on" during habituation would facilitate their ability to form an abstract categorical representation of support. By 18 months, infants comprehend "on" as referring to support events (Meints, Plunkett, Harris, & Dimmock, 2002). Possibly, then, their experience with this word as a referent for support relations might aid 18-month-old infants in attending to the relation and forming the abstract categorical representation.

Although infants also have difficulty forming a spatial category of tight-fit relations (Casasola & Cohen, 2002), infants were only tested on their ability to form a spatial category of support. Tight-fit relations are not lexically marked in English, and any difficulty that infants may experience in forming this category would be confounded with the familiarity of grouping support versus tight-fit relations into a single semantic category. For this reason, in the present studies, I only examined infants' ability to form a category of support. In addition, because the goal of these experiments was to document whether a linguistic label alone, without the aid of social context, can facilitate infants' spatial categorization, the linguistic input was presented through a stereo speaker in a habituation paradigm.

Experiment 1

In this first experiment, the effect of a familiar spatial word on 18-month-old infants' ability to form a categorical representation of support was compared with how infants perform in the task when viewing the events in silence. Infants were randomly assigned to one of two auditory conditions, silent versus familiar word. Infants in the *silent* condition viewed the spatial events without any auditory input, replicating the conditions of Casasola and Cohen (2002). Infants in the *familiar-word* condition heard recorded linguistic input containing the spatial word "on" during habituation. Rather than suddenly omitting the auditory input during the test, infants in this condition instead heard general linguistic phrases during the test trials. These test phrases omitted the word "on" but maintained as much continuity as possible between habituation and test.

The same stimuli, design, and procedure used by Casasola and Cohen (2002) were adopted. Following habituation to four different dynamic support events, infants viewed four test events. In two test events, familiar objects (i.e., those seen during habituation) depicted the familiar support relation and an unfamiliar containment relation, whereas in the two remaining test trials, novel objects depicted the familiar and unfamiliar relations. To demonstrate that they have formed an abstract categorical representation of support, infants must look significantly longer at the novel containment relation than familiar support relation when the objects are familiar and when they are novel. If infants only discriminate between the familiar and unfamiliar relation when the objects are familiar (and not when they are novel), they would demonstrate the ability to discriminate between the support and containment relations but no evidence of having formed an abstract categorical representation of support. Forming an abstract spatial category requires infants to recognize as familiar a novel instance of the support relation (i.e., the novel objects in a support relation) relative to novel objects in a containment relation. That is, infants' recognition of the support relation must be independent of the specific objects depicting the relation. Finally, if infants are unable to attend to the spatial relations, then they should only look significantly longer at the novel versus familiar objects but demonstrate no difference in looking time to the familiar versus novel spatial relation. Thus, the four test events were designed to differentiate how infants were attending to the events.

Method

Participants—Twenty-six infants between 16.5 and 19.5 months of age participated (M = 18.36 months, SD = 2.18 months). Infants were learning only English as their primary language. Eighteen infants were reported by their parents to comprehend the word "on," with approximately the same number of infants in each condition comprehending the spatial word (n = 8 for the silent condition, n = 10 in the familiar-word condition). The data from an additional 10 infants were excluded from the final sample for several reasons: 6 (5 girls, 1 boy) did not meet the habituation criterion (described below), and 4 girls became too fussy or inattentive to complete the testing session.

Infants were recruited through a letter given to the parents in the hospital at the time of their infant's birth. Parents who expressed interest were contacted once their infant reached the appropriate age for the study. All infants received an infant tee shirt.

Stimuli—The visual stimuli used in the present study were dynamic, spatial events of various pairs of objects created for use in a previous study (Casasola & Cohen, 2002). The four pairs of objects used in the habituation phase of the support condition of Casasola and Cohen were used for the habituation phase of the present experiment. One pair consisted of two hollow toy cars, one small and red and the other larger and blue. A second pair was a colorful cup and white dog bowl with colorful paw prints along the side of the bowl. A third pair comprised a Duplo (Lego) cylindrical man with horizontal red and yellow stripes and a blue Duplo (Lego)

car with yellow wheels. As the fourth pair, plastic turtles that stacked on a pole were used. A hole in the center of each turtle's shell allowed the turtles to be placed through the pole and stacked tightly on top of one another. The turtles differed in the color of their shells. For the test phase, an additional two pairs of objects were used. One pair consisted of a green peg and a yellow block with three holes along its top surface. A second pair was a red candle in the shape of a ginger man and a silver cookie cutter of the same shape.

Dynamic events were created in which the smaller object in each pair, the figure, was placed in a particular spatial relation to the larger object, the referent object. The objects in a pair first appeared side by side, with the figure to the left of the referent object. After a moment, a hand reached in, lifted the figure, and placed it either in a support or a containment relation to the referent object. For approximately half of these events, a tight-fit relation was also depicted between the objects. The turtle on the pole and the other turtles and the Duplo man on the Duplo car were tight-fit support events, and the candle in the cookie cutter was a tight-fit containment event. The three remaining support events (i.e., car on car, cup on bowl, and peg on block) and the remaining containment event (i.e., cup in bowl) depicted a loose-fit relation between the objects. The events were filmed using a Sony digital video camera, transferred to a Macintosh G4 computer using Final Cut Pro, and then converted to QuickTime movies. Each event, which was 6 s in duration, was repeated fives times without pauses to create a 30-s trial.

The auditory stimuli for the familiar-word condition were phrases spoken by a female speaker in infant-directed speech. The auditory stimuli were five phrases, one for each of the five repetitions of the spatial event within a trial. For example, for the first and fourth repetition of the event within a trial, infants heard "Look! … It goes on." The phrases were timed so that "Look" was presented prior to the hand moving the figure. The second half of the phrase, "It goes on," was presented once the figure had been placed in its spatial relation to the referent object and the hand was retreating. During the second repetition of the support event in a trial, infants heard "Wow!" prior to the hand moving the figure and heard "on" after the hand had placed the figure in its spatial relation to the referent object. For the third repetition of the event, infants heard only the specific spatial word, "on," as the figure was placed in its support relation to the referent object. For the fifth repetition of the event, infants heard "See?" prior to the hand moving the figure and "goes on" once it was in its support relation to the referent object.

The auditory stimuli used in the test phase of the familiar-word condition were general phrases that omitted the spatial word. The duration and timing of the phrases were similar to those of the habituation phase. For the first and fourth repetition of the spatial event within a test trial, infants heard "Look" prior to the action and then "See that?" once the figure was in its spatial relation to the referent object. For the second repetition of the event, infants heard "See?" prior to the action and "See what happens?" once the action was completed. For the third repetition, infants heard "See how it goes?" prior to the action and, for the fifth repetition, they heard "Look" prior to the action.

Apparatus—The experiment was conducted in adjoining control and experimental rooms. In the 3 m × 3 m experimental room, a 20-in. (51-cm) color monitor was situated on a table approximately 76 cm from the floor, designed to be at infants' eye level. A chair for infants and their parent was 127 cm from the monitor. A Panasonic camera, located under the monitor, was linked to a small Panasonic 15-in. (38-cm) television monitor in the adjoining control room. This monitor recorded the duration of infants' visual fixations during each trial. The monitor was also linked to a Panasonic VCR so that each infant could be videotaped and interobserver reliability could be determined offline by a second observer. The experimenter used a Macintosh G4 and a specially designed program, Habit 2000 (Cohen, Atkinson, & Chaput, 2000) to control the presentation of the visual and auditory events and to record infants' looking time.

Design—Infants were randomly assigned to either the silent or the familiar-word condition, resulting in 14 infants in the silent condition and 12 in the familiar-word condition, with an equal number of male and female infants in each condition. Infants in both conditions were habituated to the same four support events: turtle-on-pole, Duploman-on-car, blue-car-on-red-car, and cup-on-bowl. Following habituation, infants viewed four test trials, the first of which was an event seen during habituation. For all the infants, this familiar test event was the turtle-on-pole. Another test trial presented familiar objects (i.e., seen during habituation) in an unfamiliar containment relation. Again, this event was always the cup-in-bowl event. An additional test trial presented a novel pair of objects in the familiar support relation, the peg-on-block event, whereas a fourth test trial presented novel objects in the unfamiliar containment relation, the candle-in-cookie-cutter event. The presentation order of these last three test events was counterbalanced across participants. Previous use of these events had not yielded any spontaneous preferences for the objects or a relation (Casasola & Cohen, 2002; Casasola et al., 2003).

Procedure—During the experiment, infants sat on their parent's lap in front of the monitor in the experimental room. Parents were asked to not watch the events or direct their infants' attention. To begin the testing session, the experimenter clicked on the Habit program so that the attention-getter, a green chiming circle that contracted and expanded, would appear on the monitor. Once infants were attending to the monitor, the experimenter depressed one key on the computer keyboard to have the attention-getter replaced by an event. The experimenter depressed and held a second key on the keyboard for as long as an infant attended to the event. Infants were required to look at each event for a minimum of 2 continuous seconds in order for a look to be counted as a trial. This requirement ensured that infants would view the events long enough to view the figure being placed in its spatial relation to the referent object. The event played for as long as the infant watched and ended if the infant looked away for more than 1 continuous second or until the 30-s trial ended. The event was then replaced by the attention-getter to redirect infants' attention back to the monitor prior to the start of the next trial. Infants were presented with the four habituation support events until their looking time across three consecutive trials was less than their looking time to the first three trials of habituation or until they viewed a maximum of 20 habituation trials. Infants then viewed the four test trials. The looking times of randomly selected sample of 7 infants were coded offline by a second observer. The average correlation between the online and offline looking times was .997, with a range of .992 to .998.

Results

The first analysis was conducted to ensure that infants did not meet the habituation criterion as an artifact but had in fact significantly decreased their looking time to the events from the beginning of habituation to the beginning of the test phase. Preliminary analyses failed to reveal any difference in infants' looking times as a function of infants' reported comprehension of the spatial word "on." Consequently, this variable was not included in the analyses. Infants' looking times were analyzed in a 2 (sex: female vs. male) × 2 (condition: silent vs. familiar word) × 2 (trials: average of the first three habituation trials vs. familiar test trial that presented the turtle-on-pole habituation event) mixed-model analysis of variance (ANOVA). The analysis yielded a significant main effect of trials, $F(1, 22) = 70.92$, $p < .01$. Infants looked significantly longer during habituation ($M = 24.62$ s, $SD = 6.10$ s) than during the familiar test trial ($M = 10.31$ s, $SD = 6.85$ s). Hence, infants demonstrated a significant decrease in looking to the turtle-on-pole event from the first trials of habituation to when it was presented as the familiar test event. The analysis did not yield any other significant effects.

The average looking time of infants in each condition to each test trial is presented in Table 1. Infants' looking time during the test was examined in a 2 (sex) × 2 (condition) × 2 (spatial

relation: familiar vs. novel) × 2 (objects: familiar vs. novel) ANOVA. The analysis yielded a significant main effect for spatial relation, $F(1, 22) = 7.42$, $p < .01$, which was qualified by a significant Spatial Relation × Condition interaction, $F(1, 22) = 4.38$, $p < .05$. As can be seen in Figure 1, infants in the familiar-word condition looked significantly longer at the novel relation ($M = 15.51$ s, $SD = 10.69$ s) than at the familiar relation ($M = 10.00$ s, $SD = 7.61$ s), $F(1, 10) = 8.17$, $p < .01$. In contrast, infants in the silent condition did not, looking for an equivalent duration to the novel ($M = 11.21$ s, $SD = 8.22$ s) and familiar ($M = 10.50$ s, $SD = 7.46$ s) spatial relations, $F(1, 12) < 1$, *ns*. Thus, only infants in the familiar-word condition discriminated between the familiar and novel spatial relations. The analysis did not yield any other significant effects.

Although infants in the spatial word condition discriminated between the familiar and novel relations, did they form an abstract categorical representation of support? If they did, infants should have looked significantly longer at the novel relation than at the familiar relation when the objects were familiar and, most critically, when they were novel. Planned comparisons indicated that infants did demonstrate this pattern of looking. Infants in the familiar-word condition looked significantly longer at the novel relation than at the familiar relation with familiar objects, $F(1, 10) = 7.01$, $p < .05$, and with novel objects, $F(1, 10) = 4.99$, $p < .05$. Hence, infants responded in a manner consistent with having formed an abstract spatial category of support.

Discussion

The results of Experiment 1 indicate that infants who heard the familiar spatial word during habituation looked significantly longer at the novel than at the familiar spatial relation, both when the objects depicting the relations were familiar and when they were novel. Hence, these infants recognized the support relation as familiar independent of the specific objects used to depict the relation and, consequently, responded in a manner consistent with having formed an abstract categorical representation of support. In contrast, infants in the silent condition provided no evidence of discriminating between the familiar support relation and the unfamiliar containment relation. The difference between the two conditions suggests that the word “on” facilitated infants’ ability to form an abstract spatial category that they do not form when viewing the events in silence.

However, the results for infants in the familiar-word condition may be due to the presence of language rather than to the presence of the specific word “on.” For example, the presence of language might have increased infants’ attention to the events and consequently facilitated their ability to form the abstract categorical representation. Likewise, presenting any specific label, regardless of familiarity, may lead infants to form the abstract spatial category. A second experiment was conducted to disambiguate among these possibilities.

Experiment 2

The purpose of Experiment 2 was to begin to narrow the effect of linguistic input on infants’ ability to form an abstract categorical representation of support. Infants were again tested on their ability to form a spatial category of support, but they were randomly assigned to one of three language conditions. Infants in the *familiar-word* condition heard “on” during habituation, replicating the familiar-word condition of Experiment 1. Infants in the *general-language* condition heard general linguistic phrases during habituation that did not include the spatial word (e.g., “Look at that”). Infants in the *novel-word* condition heard the nonsense word “toke” during habituation. For the test trials, all infants heard the general-language phrases from the test phase of Experiment 1.

If the presence of language facilitates infants' ability to form an abstract categorical representation of support, then infants in each condition should form the spatial category. If the presence of any word, familiar or novel, aids infants in forming the spatial category, then only infants in the familiar-word and novel-word conditions should form the spatial category. Finally, if infants require familiarity with the word presented, then only infants in the familiar-word condition should form the abstract spatial category. Hence, the results of Experiment 2 would begin to delineate the effect of linguistic input on infants' categorization of the support relation.

In order to ensure that infants' responses in the familiar-word condition of Experiment 1 were not due to the use of a specific support and containment event, infants in Experiment 2 were habituated to four randomly selected support events from a larger array of support events. The test events also varied across infants. Because the purpose of the experiment shifted to explore if infants would respond in the same manner with a greater diversity of events, no effort was made to present an equal number of tight- and loose-fit events during the habituation and test phase. Hence, the results of Experiment 2 would also address whether the results of the familiar-word condition of Experiment 1 would be replicated with a different set of events.

Method

Participants—Thirty-six infants, 18 male and 18 female, between 16.5 and 19.5 months of age participated in the present study (M = 19.08 months, SD = 0.78 months). Twenty-seven infants, 9 in each condition, were reported by their parents to comprehend the word "on." An additional 9 infants participated in the study, but their data were excluded from the final sample for several reasons: 3 boys did not meet the habituation criterion (see Experiment 1), 4 infants (3 girls and 1 boy) became too fussy or inattentive to complete the testing session, and 2 girls were exposed to languages other than English.

Stimuli—The visual events were the same as those used in Experiment 1 with the inclusion of an additional tight-fit support event and three novel containment events. The additional novel tight-fit support event depicted one green rectangular Duplo block placed on a red rectangular Duplo block. Two of the novel containment events depicted object pairs from Experiment 1: the red and blue cars and the green peg with the yellow block. The red car was placed in a loose-fit containment relation to the inverted blue car, and the green peg was placed in a tight-fit containment relation to the yellow block. Finally, a third containment relation depicted a plush monkey being placed in a loose-fit containment relation to a wicker basket. As in Experiment 1, each event began with the smaller object in a pair to the left of the larger, referent object. After a 1-s delay, the hand entered, lifted the smaller object and placed it in a support or containment relation to the referent object. These events were created at the same time as the events in Experiment 1 and so were identical in their sequencing and timing.

New auditory stimuli were created for the habituation phase of the general-language condition. These phrases were identical in duration, timing, and prosody to the familiar word phrases (e.g., "Look … Look at that … Wow! … Yea! … Oh … Look! … Look at that … See? … Oh, yea"). The first word in a phrase was identical to the first word in each phrase of Experiment 1 (i.e., "Look," "Wow," and "See"). Only the phrases that were presented during or after completion of the action were different. For the first and fourth iteration of the event within a trial, infants heard "Look" prior to the hand lifting the figure and then "Look at that" (rather than "it goes on") once the figure was in its spatial relation to the referent object. For the second iteration of the event, infants heard "Wow" prior to the hand lifting the figure and then "Yea" (rather than "on") once the figure was supported on the referent object. For the third iteration of the event, infants heard "Oh" as the figure was being placed on the referent object.

For the fifth repetition of the event, infants heard “See” prior to the hand entering the scene and “Oh, yea” once the figure was on the referent object.

New auditory stimuli were also created for the novel-word condition. The same habituation phrases as the familiar-word condition were used, but the novel word “toke” replaced “on” in each phrase. Hence, infants heard “It goes toke” once the figure was in its spatial relation to the second object for the first and fourth iteration of the event within a trial. For the second iteration of the event, infants heard “Toke” once the figure was supported on the referent object. For the third iteration of the event, infants heard “Toke” as the figure was being placed on the referent object. For the fifth repetition of the event, infants heard “Goes toke” once the figure was on the referent object. This auditory input was identical in duration, timing, and prosody as the familiar-word and general-language input. The auditory stimuli used in the test trials were the same as those used in the test phase of Experiment 1 and did not differ across the three language conditions.

Apparatus, design, and procedure—The apparatus and procedure were the same as in Experiment 1 with the following exceptions. Infants were randomly assigned to the familiar-word, general-language, or novel-word condition, resulting in 12 infants (6 male, 6 female) in each condition. Of the six support events possible (i.e., car-on, cup-on, peg-on, turtle-on, green Duplo block-on, or Duplo man-on), infants viewed four of these, chosen at random. The four events presented during the test trials also differed across infants. For the familiar objects in a familiar relation test trial, infants viewed one of the support events presented during habituation, chosen randomly from the four events viewed during habituation. Likewise, for the familiar objects in a novel relation test event, infants viewed one of the object pairs presented during habituation but in a containment relation rather than in a support relation. Because only three of the six possible support events had containment counterparts that used the same objects, this event was the car-in, the cup-in, or the peg-in event, depending on which of these had been viewed during habituation. The novel objects in a familiar relation test event presented a support event not viewed during habituation, and the novel objects in a novel relation test event presented a novel pair of objects in a containment relation. Infants in each linguistic condition were matched for the habituation and test events viewed. Hence, any difference in performance across the three conditions could not be attributed to the particular events presented. The looking times of 13 randomly chosen infants were recorded offline by a second observer and yielded an average correlation of .994 (range = .990 to .999) between the online and offline looking times.

Results

The first analyses compared infants’ looking time during the beginning of habituation to the familiar test event. Preliminary analysis again revealed no difference in the performance of infants reported by their parents to comprehend the word “on” versus those who did not. This variable was consequently excluded in the analyses. Infants’ looking times were examined in a 2 (sex: male vs. female) × 3 (condition: familiar word vs. general language vs. novel word) × 2 (trials: the average of the first three habituation trials vs. the familiar test trial) mixed-model ANOVA. The analyses yielded only a significant effect for trials, $F(1, 30) = 379.71$, $p < .01$. Infants demonstrated a significant decrease in looking time from the beginning of habituation ($M = 26.64$ s, $SD = 4.51$ s) to the beginning of the test ($M = 7.60$ s, $SD = 4.96$ s).

The next analyses examined infants’ ability to discriminate the change in objects and spatial relation during the test. Presented in Table 2 are the means and standard deviations of infants’ looking time to each test trial in each condition. Infants’ looking times during the test were analyzed in a 2 (sex) × 3 (condition) × 2 (objects: familiar vs. novel) × 2 (spatial relation: familiar vs. novel) mixed-model ANOVA. The results yielded a significant effect for objects,

$F(1, 30) = 31.69$, $p < .01$. Infants looked significantly longer at the novel objects ($M = 14.31$ s, $SD = 7.50$ s) than at the familiar objects ($M = 9.02$ s, $SD = 6.03$ s). The analysis also yielded a significant effect for spatial relation, $F(1, 30) = 6.83$, $p < .02$, which was qualified by a significant Spatial Relation × Condition interaction, $F(2, 30) = 4.34$, $p < .05$. As can be seen in Figure 2, infants in the familiar-word condition looked significantly longer at the novel relation ($M = 16.53$ s, $SD = 8.72$ s) than at the familiar relation ($M = 9.97$ s, $SD = 6.70$ s), $F(1, 10) = 10.80$, $p < .01$. In contrast, infants in the general-language condition did not ($M = 11.75$ s, $SD = 6.69$ s for the novel relation; $M = 10.11$ s, $SD = 4.52$ s for the familiar relation), $F(1, 10) = 2.22$, *ns*. Infants in the novel-word condition also failed to look significantly longer at the novel relation ($M = 10.60$ s, $SD = 6.85$ s) than at the familiar relation ($M = 11.02$ s, $SD = 8.00$ s), $F(1, 10) < 1$, *ns*. Thus, only infants who heard the familiar spatial word during habituation provided evidence of discriminating between the familiar and novel spatial relations.

Did infants in the familiar-word condition provide evidence of having formed an abstract categorical representation of support? Using planned comparisons, I examined infants' looking time to the familiar versus novel relation separately for the familiar and novel objects. Infants in the familiar-word condition looked significantly longer at the novel relation than at the familiar relation when the objects were familiar, $F(1, 10) = 8.77$, $p < .05$, and when they were novel, $F(1, 10) = 5.07$, $p < .05$. Infants in the familiar-word condition thus provided evidence of having formed an abstract categorical representation of support. In contrast, infants in the general-language and novel-word conditions did not. These infants failed to significantly increase their looking time to the novel relation relative to the familiar relation with familiar objects (Fs < 1, *ns*) and with novel objects, Fs$(1, 10) < 2.20$, $p > .16$. However, these infants did discriminate between the familiar and novel objects, $F(1, 10) = 14.00$, $p < .01$, and $F(1, 10) = 5.43$, $p < .05$, respectively. Thus, infants in the general-language and novel-word conditions attended to the change in objects but not the change in spatial relations.

Discussion

The results of the familiar-word condition of Experiment 2 replicate those of the familiar-word condition of Experiment 1. Hearing "on" with each example of support during habituation facilitated infants' ability to form an abstract categorical representation of support. In contrast, general linguistic phrases or a novel spatial word did not. Infants in these conditions provided no evidence of discriminating between the familiar support relation and the novel containment relation. However, these infants were not so overwhelmed by the addition of linguistic input that they failed to respond to any changes in the events. These infants did discriminate the change in objects. In sum, the results of Experiment 2 indicate that only the familiar word "on," and not the presence of language in general or a novel word, aids infants in forming an abstract categorical representation of support.

General Discussion

To form an abstract categorical representation of support, infants must be able to recognize the relation across both familiar and novel objects. That is, infants must perceive the relational commonality independent of the specific objects that depict the relation. At least for the spatial relation of support, the present experiments provide evidence that a familiar word can aid 18-month-old infants in forming an abstract categorical representation of the relation. In both Experiments 1 and 2, hearing the word "on" with each habituation support event led infants to discriminate the familiar support relation from a novel containment relation, regardless of object familiarity or novelty. This result was replicated across the two experiments, which used different events, indicating that the effect was not due to a specific set of events. In contrast, infants who viewed the events in silence in Experiment 1 did not form the spatial category, providing further support that infants have difficulty forming an abstract spatial category of

support when viewing the events in silence (Casasola & Cohen, 2002). Likewise, infants in Experiment 2 who heard general linguistic phrases or a novel spatial word also did not form the abstract spatial category. Hence, simply adding linguistic phrases or a novel word to the support events during habituation was insufficient to aid infants in forming the spatial category. In sum, the results of the present experiments begin to narrow the facilitative effect of language on infants' categorization of a support relation to the presence of the familiar word "on."

Although the present results ruled out the facilitative effect of the word "on" to the presence of general linguistic phrases and a novel word, the exact reason for the results of infants in the familiar-word condition of Experiments 1 and 2 could, nonetheless, be explained by a number of possibilities. It may be that any familiar word, and not necessarily a familiar *spatial* word, will facilitate infants' categorization of support. However, if presenting familiar words leads infants to form an abstract spatial category, then infants in the general-language condition should have formed the spatial category. Because they did not, this explanation seems unlikely. However, it may be that presenting any *consistent* familiar word may lead infants to form the abstract category, a possibility that must be ruled out in future investigations. Thus, the present studies cannot pinpoint the facilitative effect of the word "on" to a familiar spatial word. In addition, future investigations must also explore whether the spatial word must match the spatial relation presented. Perhaps simply presenting any familiar spatial word is sufficient to draw infants' attention to the relation and, thus, facilitate their ability to form the abstract category.

Similarly, a number of reasons can explain the difference in results between infants who heard "on" and those who heard "toke." The two words not only differed in their degree of familiarity but also differed phonetically. "Toke" contains one more consonant than "on." This phonetic difference may have influenced infants' performance on the spatial categorization task. Because many children's early spatial words begin with a vowel (e.g., *up, in, on, off*), infants may have interpreted "toke" as a noun, providing one reason the infants attended to the objects and not the spatial relation. In addition, both "on" and "toke" were presented either in isolation or in a general verb frame (i.e., "goes ____"), so that there was minimal information from the syntactic context of the sentence to specify path of motion or location. Had a more specific verb frame been used (e.g., "puts it ____"), infants may have had sufficient information to correctly interpret "toke" as referring to the relation. Thus, syntactic and phonetic factors, in addition to the familiarity of the words, may have contributed to the difference between infants in the familiar-word versus novel-word conditions.

In sum, the present results are only a first step in exploring the effect of linguistic input on infants' ability to form an abstract categorical representation of a spatial relation. For this reason, the results should not be taken as evidence that a novel word cannot facilitate infants' ability to form an abstract spatial category. If tested under different conditions, such as in a naturalistic setting with an experimenter, or with the novel word in a complete sentence so that there is a syntactic context, infants might be able to form the abstract spatial category of support. Consistent with this possibility, Casasola, Wilbourn, and Yang (in press) found that English-speaking toddlers of 21 months learned to form a novel semantic spatial category when interacting with an experimenter in a naturalistic training session and when the novel word was presented in the phrase "I put it X." It is possible that the same effect could be obtained with infants as young as 18 months. The syntactic context of a novel word is sufficient to bias young children to interpret the word as referring either to an object or a location (Landau & Stecker, 1990). Thus, one direction for future study is to explore whether this sensitivity is in place by 18 months.

Although the exact reason why the word "on" facilitated infants' ability to form an abstract spatial category must be further explored, the present findings do lend support to Bowerman

and Choi's (2001) argument that linguistic input can facilitate the development of an abstract spatial category. The present results provide the first evidence that a familiar word can facilitate the formation of a spatial category. Hence, familiar language leads children as young as 18 months to recognize a particular relational similarity across contexts and to form the abstract spatial category that they have difficulty forming in the absence of the familiar word. Because the linguistic input was presented through stereo speakers, the performance of the infants in the familiar-word conditions could not be attributed to cues from an experimenter or a social context. However, it was interesting that infants' performance did not differ as a function of their reported comprehension of "on." One reason for this finding may be that nearly all of the infants in each condition were reported to comprehend "on," such that there were an insufficient number of infants who did not understand the label to detect any difference between the two groups of infants.

The present experiments add to a growing literature on the relation between cognitive development and early linguistic development (Balaban & Waxman, 1997; Gentner & Namy, 1999; Gopnik et al., 1996; Namy & Gentner, 2002; Waxman & Booth, 2001; Waxman & Hall, 1993; Waxman & Markow, 1995). The present results demonstrate that a specific label directs infants' attention not only to commonalities across objects and object properties (Balaban & Waxman, 1997; Booth & Waxman, 2002; Roberts & Jacob, 1991; Waxman & Booth, 2001) but also to commonalities in a spatial relation. Hearing the word "on" presented with each example of support during habituation aided infants in attending to the support relation, a commonality that was not apparent to infants when viewing the events in silence. The present findings demonstrate how a common label motivates infants to note whatever commonality may be present in a dynamic event, even if the commonality is unrelated to the objects in the events. Thus, the facilitative effect of relational language on noting relational commonalities is present earlier in development than the preschooler years (Loewenstein & Gentner, in press).

Of course, the results raise the inevitable question of how language exerts its influence on infants' spatial categorization. Clearly, the familiar word "on" increased infants' attention to the support relation during habituation. Although the general-language phrases and the novel word may have increased infants' attention to the events, the results indicate that heightened attention to the events was not sufficient to direct their attention to the support relation specifically. Thus, the familiar word "on" facilitated infant's ability to form an abstract categorical representation of the relation by aiding them to attend to the relevant aspect of the event, the support relation. Less clear, however, is whether the familiar spatial word provided the only vehicle through which infants could learn to form the abstract spatial category (a competence explanation) or whether the word simply provided the needed scaffolding to form a spatial category infants could already form (a performance explanation). That is, was the word "on" responsible for the acquisition of the concept or only in making the task easier for infants to form a category that they might form in an easier task?

The present experiments cannot disambiguate between these two possibilities. Each is a feasible explanation for the effect of the word "on" on infants' categorization of the support relation. Recent evidence shows that 14-month-old infants can form an abstract categorical representation of support if habituated to only two loose-fit support events (Casasola, in press). Thus, under particular testing conditions, infants can form an abstract categorical representation of support, indicating that language is not a necessary element in infants' ability to form this spatial category. However, infants in the present study viewed both tight-fit and loose-fit examples of support, events that are very distinct from one another. Given the diversity of the support events presented, it is possible that infants would never learn to group these different types of support events into a single category unless motivated to do so by a specific label. Thus, in instances in which the perceptual similarity among the events is low, a specific

label may be necessary for infants to learn to group disparate events into a single spatial category (see Waxman & Markow, 1995, for a similar argument with object category formation).

Finally, it is worth considering how language may be interacting with the nonlinguistic mechanisms that guide infants' ability to form an abstract categorical representation of a spatial relation. Infants' ability to form an abstract categorical representation of a spatial relation has been argued to follow a specific-to-abstract progression (Casasola & Cohen, 2002; Quinn et al., 1996, 2003). Infants first learn to recognize a relation between specific objects prior to recognizing the relation between novel objects. For example, 3-month-old infants only recognize "above" versus "below" between familiar objects (Quinn, Polly, Furer, Dobson, & Narter, 2002), whereas 6-month-old infants can generalize these relations to novel objects (Quinn et al., 1996). Similarly, 6-month-old infants only recognize the spatial relation "between" when presented with familiar objects but cannot generalize the "between" spatial relation to novel objects until they are 9 months of age (Quinn et al., 2003). In each case, infants' recognition of a spatial relation first depends on familiar objects. At a later point in development, infants' recognition of a spatial relation becomes independent of the specific objects that comprise the relations, and they gain the ability to form an abstract categorical representation of the spatial relation. However, prior to learning to attend to the relation between familiar objects, infants first learn to attend to the objects in the event (Casasola & Cohen, 2002). Thus, infants progress from first discriminating the objects in a spatial event, to discriminating the relation between familiar objects, to discriminating the relation between novel objects and, hence, forming the abstract categorical representation of the relation.

An interesting possibility is that language modulates this specific-to-abstract progression by advancing infants further along the progression when a familiar word is presented or to an earlier point in the progression when the linguistic input are general phrases or an unfamiliar word. Although infants in the silent condition of Experiment 1 failed to discriminate between the familiar support relation and the novel containment relation with familiar objects, infants previously tested with the same stimuli and task provided evidence of doing so (Casasola & Cohen, 2002), as did infants tested with different support events (Casasola, Bhagwat, & Ferguson, in press). Why infants in the silent condition of Experiment 1 did not replicate this result is a matter of speculation. These infants failed to attend to changes in either the objects or the spatial relation, suggesting that they may not have been sufficiently engaged in the task. However, providing general linguistic phrases or a novel spatial word appeared to increase infants' attention to the events such that they attended to the change in objects. Thus, infants in the present experiments progressed from not attending to any changes in the events to attending to the change in objects, the first step in the specific-to-abstract progression. However, when a familiar word was presented, infants advanced to the last step in the developmental progression of forming the abstract category. This pattern of findings suggests that language can regulate where infants fall in the specific-to-abstract progression. Of course, infants' linguistic abilities likely impact the effect of language on this progression. Currently, this possibility is only suggested by the results and requires systematic testing, both with other spatial relations and with infants at various levels of comprehending spatial language. The present results, nonetheless, have established the first step needed to continue this line of research: evidence that a specific word can aid infants in forming an abstract categorical representation of a spatial relation.

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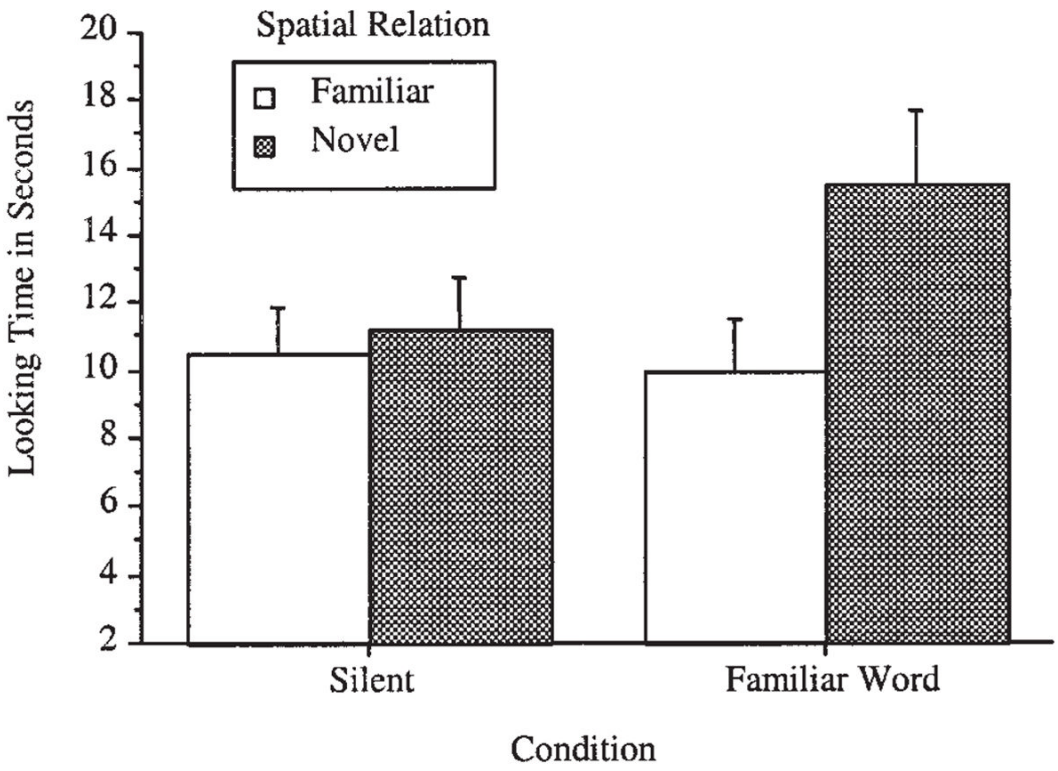

Figure 1.
The looking times (with standard errors) of the 18-month-old infants in each condition of Experiment 1 to the familiar versus novel spatial relation when the objects were familiar versus when the objects were novel.

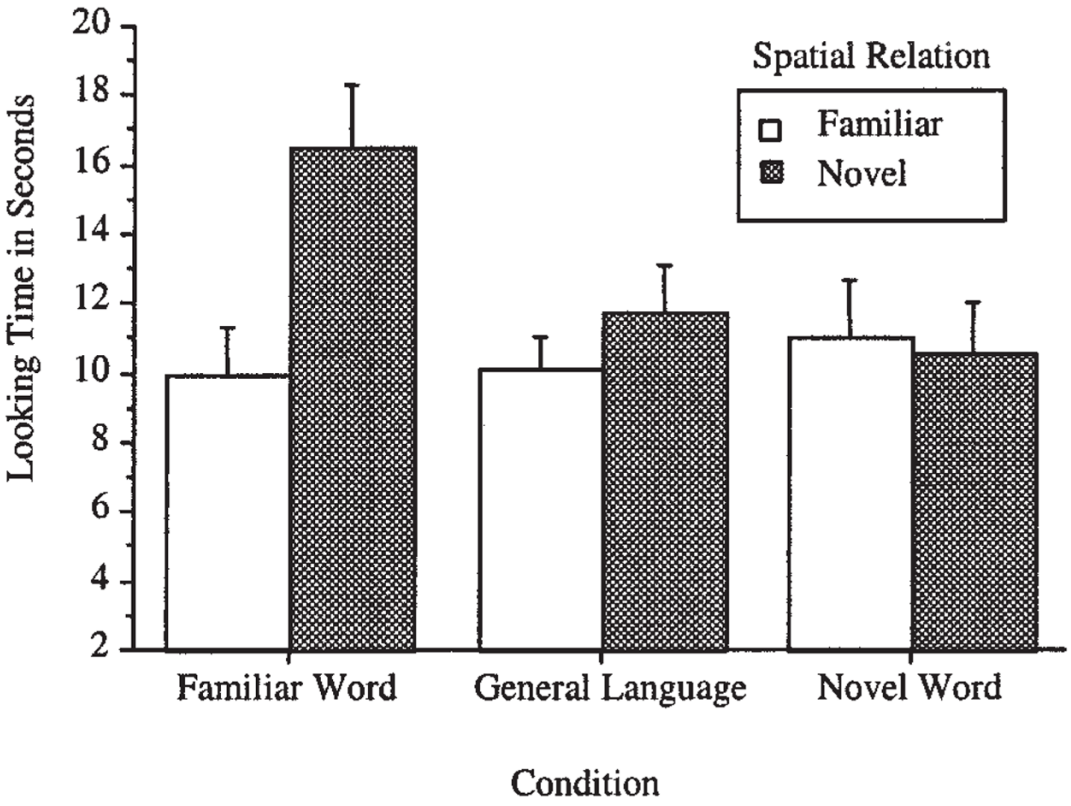

Figure 2.
The looking times (with standard errors) of the 18-month-old infants in the familiar-word, general-language, and novel-word conditions of Experiment 2 to the familiar versus novel spatial relation when the objects were familiar versus when the objects were novel.

Table 1

Infants' Mean Looking Time and Standard Deviation (in Seconds) to Each Test Event Across Each Condition of Experiment 1

	Silent condition		Familiar word condition	
Test trial	***M***	***SD***	***M***	***SD***
Familiar objects in a familiar relation (turtle-on event)	9.95	6.89	10.73	7.08
Familiar objects in a novel relation (cup-in event)	10.81	7.17	16.71	10.62
Novel objects in a familiar relation (peg-on event)	11.04	8.03	9.27	8.13
Novel objects in a novel relation (candle-in event)	11.61	9.41	14.31	10.75

Table 2

Infants' Mean Looking Time and Standard Deviation (in Seconds) to Each Test Event Across Each Condition of Experiment 2

	Familiar word		General language		Novel word	
Test trial	***M***	***SD***	***M***	***SD***	***M***	***SD***
Familiar objects in a familiar relation	5.88	4.15	8.83	4.73	8.10	5.79
Familiar objects in a novel relation	13.33	8.00	9.40	5.51	8.58	5.87
Novel objects in a familiar relation	14.07	6.33	11.40	4.30	13.93	9.05
Novel objects in a novel relation	19.73	8.53	14.10	7.15	12.63	7.38