



Published in final edited form as:

Dev Psychol. 2009 May ; 45(3): 711–723. doi:10.1037/a0015475.

Learning to Form a Spatial Category of Tight-Fit Relations: How Experience With a Label Can Give a Boost

Marianella Casasola¹, Jui Bhagwat¹, and Anne S. Burke^{1,2}

¹ Department of Human Development, Cornell University, Boston

² Department of Medicine, Brigham and Women's Hospital, Boston

Abstract

Two experiments explored the ability of 18-month-old infants to form an abstract categorical representation of tight-fit spatial relations in a visual habituation task. In Experiment 1, infants formed an abstract spatial category when hearing a familiar word (*tight*) during habituation but not when viewing the events in silence or when hearing a novel word. In Experiment 2, infants were given experience viewing and producing tight-fit relations while an experimenter labeled them with a novel word. Following this experience, infants formed the tight-fit spatial category in the visual habituation task, particularly when hearing the novel word again during habituation. Results suggest that even brief experience with a label and tight-fit relations can aid infants in forming an abstract categorical representation of tight-fit relations.

Keywords

infant categorization; spatial cognition; spatial language

Providing labels for the objects and events in an infant's visual world can facilitate his or her ability to learn about the environment. Infants of 12 months attend longer to objects that have been labeled relative to those that remained unlabeled (Baldwin, 1991). Labels also motivate infants to abstract commonalities to form categories that they might not otherwise form, with respect to both objects (e.g., Balaban & Waxman, 1997; Booth & Waxman, 2002; Roberts & Jacob, 1991; Waxman & Markow, 1995) and dynamic events (Casasola, 2005a; Casasola & Bhagwat, 2007; Pruden & Hirsh-Pasek, 2006). However, the extent to which labels are needed in the formation of specific categories remains unclear and is an issue that has received much discussion, particularly with respect to the spatial categories that infants form (e.g., Bowerman & Choi, 2001; Choi & Bowerman, 1991; Hespos & Spelke, 2004; Mandler, 1996). In the present two experiments, we explored this issue by examining 18-month-old English-learning infants' formation of a spatial category of tight-fitting relations, a distinction that is not lexically marked in English but which forms the basis of the Korean semantic category of *kkita* (further described below). Infants were tested on their ability to form a spatial category of tight fit when provided with a specific label or when viewing the events in silence. The studies also explored whether the effect of a specific label on infants' spatial categorization differed as a function of label familiarity and, in a second study, as a function of firsthand experience with tight-fit relations. Together, these studies represent an effort to begin to outline how infants' experiences with particular labels and tight-fit relations may differentially influence the spatial categories that they learn to form.

The spatial category of tight fit used in the present experiment is based on the Korean semantic category of *kkita* (Choi & Bowerman, 1991). Korean speakers use the spatial morpheme *kkita* to describe actions that result in a tight-fit relation between two objects, as in the case of placing a cork in a bottle, a Lego block on another, or a ring on a finger (Bowerman, 1996; Bowerman & Choi, 2001). The morpheme (a verb ending) is applied to both tight-fit containment and tight-fit support events and, thus, intersects the English semantic categories of “in” and “on.” *Kkita* is among the early words produced by Korean-language learning children, with some children producing it in reference to both tight-fitting containment and tight-fitting support relations as young as 14 months of age (Choi & Bowerman, 1991). When tested on their comprehension of *kkita*, Korean toddlers of 18 to 23 months demonstrated that their comprehension of this spatial term also extends to actions resulting in a tight-fit containment relation as well as those resulting in a tight-fit support relation (Choi, McDonough, Bowerman, & Mandler, 1999). These findings show that, early in their second year, Korean infants have begun to acquire this semantic category.

One reason why *kkita* appears early in Korean children’s spatial vocabularies may stem from an early sensitivity to tight-fitting relations between objects (Bowerman, 1996; Choi & Bowerman, 1991; Mandler, 1996). Five-month-old infants, raised in a monolingual English environment, easily discriminate between tight-fit and loose-fit containment events (Hespos & Spelke, 2004). They also respond to a tight-fit support event (a ring placed tightly around a pedestal) as more similar to a tight-fit containment event (a cylinder placed in a container) than to a loose-fit support event (a cylinder placed on a pedestal). That is, infants as young as 5 months of age can generalize a tight-fit support event with simple objects to a tight-fit containment event with similar objects. Even when viewing more perceptually variable and complex objects presented on video, both Korean- and English-language learning infants of 9 to 14 months can form an abstract spatial category of tight fit that discriminates between tight-fit containment and loose-fit containment (McDonough, Choi, & Mandler, 2003). Both sets of results highlight how infants from different linguistic environments are sensitive to actions that result in a tight fit between two objects, providing evidence for a perceptual and conceptual foundation on which to acquire a label for tight-fit events.

However, English-language learning infants do not always readily generalize tight-fit to both tight-fit containment and tight-fit support, similar to Korean infants’ use of “*kkita*” (Choi & Bowerman, 1991; Choi et al., 1999). Whereas English-learning infants of 5 months can make this generalization (Hespos & Spelke, 2004), older English-learning infants of 10 and 18 months struggle in forming a broader, more inclusive category of tight-fit (i.e., one that includes both tight-fit containment and tight-fit support events), at least when the objects used in the events are more complex, perceptually distinct from each other, and presented on video. When habituated to videotaped events of both tight-fit containment and tight-fit support, English-learning infants of 10 and 18 months failed to form the abstract categorical representation of tight-fit (Casasola & Cohen, 2002). Possibly, by 10 and 18 months, English-learning infants have become highly sensitive to the distinction between containment and support and cannot disregard it to generalize tight fit across this category boundary. By as young as 6 months, infants form an abstract categorical representation of containment as distinct from support (Casasola, Cohen, & Chiarello, 2003), and by 14 months infants can form an abstract spatial category of support under certain circumstances (Casasola, 2005b). Infants of 14 months also map novel labels onto containment and support events (Casasola & Wilbourn, 2004), and infants of 15 months comprehend the word *on* as referring to a support relation (Meints, Plunkett, Harris, & Dimmock, 2002). Diary studies also show that infants are producing the word *in* to describe containment events and the word *on* to describe support events by 17 to 19 months (Choi & Bowerman, 1991; Tomasello, 1987). This preverbal and linguistic sensitivity to the distinction between containment and support may explain why older English-language learning infants fail to form a broader spatial category of tight-fit relations that

includes both tight-fit containment and tight-fit support when tested in a visual habituation task.

A related possibility is that infants do not recognize the common tight-fit relation when familiarized with both tight-fit containment and tight-fit support events. For instance, when familiarized to a single, three-dimensional event with simple objects (such as containers or tubes) and tested with objects that are perceptually very similar to those viewed during familiarization, 5-month-olds generalize from a tight-fit support event to a tight-fit containment event (Hespos & Spelke, 2004). Under these testing conditions, infants do generalize a tight-fit relation from support to containment (and presumably, from containment to support). Even when familiarized with six videotaped scenes of tight fit that depict highly variable and more complex objects, infants as young as 9 months form an abstract category of tight fit (McDonough et al., 2003). Thus, infants' difficulty is not due solely to viewing videotaped events or events with perceptually variable objects. However, in the study conducted by McDonough et al., infants were familiarized with either tight-fit containment or loose-fit containment events wherein they only had to attend to the distinction between tight fit versus loose fit within containment in order to form the spatial category. Perhaps it is the presentation of perceptually diverse objects along with tight-fit containment and tight-fit support events during habituation that creates a categorization task that is difficult for infants. That is, infants' ability to form a spatial category of tight fit may vary as a function of the variability in the stimuli and the demands of the task, similar to infants' categorization of objects (e.g., Oakes, Coppage, & Dingel, 1997; Quinn, Eimas, & Rosenkrantz, 1993). As the variability of the events increases, infants begin to display greater difficulty in recognizing the relational commonality of tight fit and, consequently, do not form the abstract categorical representation.

Thus, whereas infants possess the perceptual ability to discriminate between tight-fit and loose-fit relations and the conceptual ability to form abstract categorical representations of tight-fit relations within a containment relation, the ability to form a broader category of tight fit (one that includes both tight-fit containment and tight-fit support and one that is analogous to the events described by the Korean semantic category of *kkita*) is more challenging. This difficulty may exist because infants cannot disregard the distinction between tight-fit containment and tight-fit support, because they fail to note the relational commonality of tight-fit with more perceptually variable events, or both. In these instances, providing a specific label while viewing the different instances of tight fit might provide the crucial impetus that would direct infants' attention to the relevant commonality in these events and assist them in forming a broader, more diverse category of tight fit, one consistent with the Korean semantic category of *kkita*.

Several studies provide initial support for the facilitative effect of labels on infants' attention to spatial events. Gertner, Baillargeon, and Fisher (2005) found that providing a count noun altered infants' reasoning about hidden objects in various types of spatial events. Pruden and Hirsh-Pasek (2006) reported that providing infants of 7 months with a novel label aids them in abstracting the path of motion in animated, dynamic events. Along similar lines, Casasola and Bhagwat (2007) found that providing a novel label for perceptually diverse support events facilitated 18-month-old infants' ability to form the abstract categorical representation of a support spatial relation. In a word-learning task, toddlers of 20 to 22 months learned to attend to a tight-fit relation and to disregard the distinction between containment and support when different examples of a tight-fit relation were labeled with a novel word (Casasola, Wilbourn, & Yang, 2006). When tested on their comprehension of the novel word, the toddlers, all monolingual English speakers, generalized the novel word to new examples of both tight-fit containment and tight-fit support. Together, these findings suggest that providing English-language learning infants with a novel label for the tight-fit relations might facilitate their ability to form the abstract categorical representation of tight fit.

The present two experiments were designed to explore this possibility. In Experiment 1, infants heard a specific label with each demonstrated example of tight fit during habituation while another group viewed the events in silence. Because tight fit is not lexically marked in English, and infants had to learn to disregard the distinction between tight-fit containment and tight-fit support events, this first experiment compared infants' ability to form a spatial category of tight fit after hearing the familiar English term *tight* versus a novel word. A second experiment was conducted to explore whether hearing a novel word for the relation in person might facilitate infants' subsequent spatial categorization in the visual habituation task. Thus, in Experiment 2, prior to participating in the visual habituation task, infants were given firsthand experience viewing and producing tight-fit relations as an experimenter provided a novel label for two tight-fit relations. Together, the two studies were designed to outline the degree to which linguistic input and, in Experiment 2, firsthand experience with tight-fit relations, can facilitate infants' spatial categorization of tight fit and whether labels with which infants have had previous experience may be more effective than unfamiliar labels in shaping the spatial categories that infants learn to form.

Experiment 1

In Experiment 1, we examined whether providing a specific label during habituation facilitates infants' formation of an abstract categorical representation of a tight-fit spatial relation. During habituation, infants of 18 months heard a specific label for two tight-fit containment and two tight-fit support events. We also explored whether a possibly familiar label would be more effective in facilitating infants' spatial categorization than a novel label. Although English does not have a semantic spatial category based on tight fit, tight-fitting relations can be described in English (e.g., one could say, "he placed it tight" or "it is snug"). The term "tight" was chosen because it was believed to be a term with which infants of 18 months had some experience. An informal sample of parents noted that they used the word *tight* on occasion with their infant, and several infant books, distributed for free to families in the community, included this term. We reasoned that infants' familiarity with the word *tight* might facilitate their attention to the tight-fit relation in a manner that a novel label may not.

To test this possibility, we randomly assigned infants in Experiment 1 to one of three habituation conditions. One group of infants viewed the events in silence. A second group heard the English term *tight* during habituation, and a third group heard the novel label (*toke*). If providing a specific label with each example of tight fit during habituation facilitates infants' spatial categorization, then infants in both label conditions (familiar and novel label) should form the abstract categorical representation of tight fit, whereas infants in the silent condition should not. In contrast, if a familiar word is more effective in directing infants' attention to the tight-fit relation, then only infants in the familiar word condition would be expected to form the tight-fit category.

Method

Participants—The final sample consisted of 36 infants of 18 months ($M = 18.10$ months, $SD = 0.97$ months), of which 18 were female and 18 were male. All infants were from monolingual, English-speaking homes, and nearly all infants were Caucasian and from middle-class families. Parents were sent a letter at the time of their child's birth inviting them to participate in studies of infant learning and development. If they expressed interest, parents were sent a second letter once their infant was nearing 18 months of age, followed by a telephone call to set an appointment. An additional 8 infants participated in the study but were not included in the final sample for the following reasons: One infant did not meet the habituation criterion (described below), 5 became too fussy or inattentive to complete the procedure, and 2 infants were exposed regularly to languages other than English. All participants were given a T-shirt, spill-proof cup, or bib in appreciation for their participation.

Stimuli—The stimuli used during the habituation and test phases were videotaped dynamic events consisting of a referent and a figure object. Each event began with the two objects side by side, with the figure object to the left of the referent object. After 1 s, a hand entered the scene, lifted the figure, and placed it in a tight-fit relation to the referent object. The hand then exited the scene, and the tight-fit relation between the two objects was displayed for an additional second.

The visual stimuli for the habituation phase were four dynamic events, each depicting a tight-fit relation between a figure and its referent object. Two of the habituation events depicted a tight-fit containment relation: (a) a red candle in the shape of a gingerbread man that was placed tightly inside a silver cookie cutter of the same shape and (b) a green peg that fit snugly in a hole of a plastic yellow block. The remaining two habituation events depicted a tight-fitting support relation: (c) a red and yellow striped Duplo figure that snapped tightly on a blue Duplo car and (d) a green Duplo block that interlocked tightly when placed on a red Duplo block. The top two rows of Figure 1 depict the hand in the process of placing each figure in its tight-fit relation to the referent object.

In addition to these visual events, two sets of phrases were created for the habituation phase of the study: one for the familiar word condition and one for the novel word condition. Each set was recorded by the same female speaker in infant-directed speech and consisted of five phrases, one for each of the five repetitions of the event within a trial (see Table 1). In each condition, four of the five phrases were timed such that the initial attention-grabbing word (e.g., “Look,” “Wow,” “See”) was presented as the hand reached for the figure object. The second part of each phrase was uttered as soon as the figure object was placed in a tight-fit relation to the referent object and the hand was retreating. The exception was the third repetition of the event within a trial, in which infants heard “Tight” or “She puts it toke!” as the figure was placed in its tight-fit relation to the referent.

The two word conditions were identical in the attention-grabbing words used and the point at which these words were presented in the events. The two conditions were also the same with respect to the point at which the second half of each phrase began within the event (i.e., once the figure was in its spatial relation to the referent object). However, because the novel word condition had longer phrases (“She puts it toke” vs. “Goes tight”), infants in this condition heard the latter half of the phrases for a longer duration into the events. The reasoning for using different syntactic frames across the two word conditions was based on previous findings. By 14 months, infants are sensitive to the distinction between count nouns and adjectives and use this information in attending to commonalities in objects and their properties (e.g., Booth & Waxman, 2003), and by 18 months, infants are sensitive to the syntactic cues that signal a count noun versus a verb (Echols & Marti, 2004). With respect to spatial categorization, infants can use a minimal and general syntactic frame with a familiar spatial term to facilitate their spatial categorization but require a more informative syntactic frame when presented with a novel word (Casasola, 2005a; Casasola & Bhagwat, 2007). To ensure that infants in the familiar word condition were relying more on the familiarity of the word than on the syntactic frame in which it was presented, the spoken word *tight* was presented in a general syntactic frame that would provide minimal cues to its meaning (e.g., “It goes tight”) or, alternatively, was presented in isolation (e.g., “tight”). In contrast, the novel word was placed in a richer syntactic frame that would cue infants, along with the familiar verb *put*, that the novel word referred to the resulting tight-fit spatial relation between the two objects (e.g., “She puts it toke”).

The visual stimuli for the test phase included four pairs of objects (see the bottom two rows of Figure 1). Two of these object pairs were presented during habituation: (a) the candle and the cookie cutter, and (b) the peg and the yellow block. While the candle was still placed in a tight-fit containment relation to the cookie cutter (as it was during habituation), the peg was placed

in a loose-fit support relation to the block (rather than in a tight-fit containment relation). The remaining two pairs of objects were presented for the first time during the test phase. A set of three colorful turtles and a pole depicted a tight-fit support relation. One turtle was placed tightly on the pole and on top of the two other turtles. Finally, a small colorful cup was placed in a white dog bowl adorned with multicolored paw prints, depicting a loose-fit containment relation.

Infants in the two word conditions heard attention-getting phrases during the test trials that did not include the familiar or the novel word. These phrases were identical across the word conditions. Specifically, for the first and fourth repetition of the spatial event within a test trial, infants heard “Look” as the hand reached for the figure object and then “See that?” after the figure had been placed in relation to the referent object. For the second repetition, infants heard, “See?” prior to the action and “See what happens” after the action was completed. For the third repetition, the infants heard “See how it goes?” before the action, and for the fifth repetition, they heard only “Look!” before the action.

The four test events were designed to assess the basis upon which infants were processing the events. The candle-in-cookie-cutter habituation event was presented again during the test phase to provide a baseline of infants’ looking time to an event that had both familiar objects and the familiar tight-fit relation relative to those events that presented a change in the objects, the tight-fit relation, or both. If infants were attentive only to the objects in the events, then they would be expected to look significantly longer at the two test events with novel objects (the cup and the turtles) than at the two test events with objects presented during habituation (the candle and the green peg). If infants formed the abstract categorical representation of the tight-fit spatial relation, they would be expected to look significantly longer at the two test events with a novel loose fit relation (the events with the peg and the cup) relative to the two test events with the familiar tight-fit relation (the events with the candle and the turtles). If infants demonstrated this pattern only with the objects seen during habituation, they would provide evidence of discriminating between the tight-fit and loose-fit spatial relations, but no evidence of having formed an abstract categorical representation of tight fit. Rather, it is their ability to look significantly longer at the novel loose-fit relation relative to the familiar tight-fit relation with both familiar and novel objects that would show that infants could generalize the relation to a novel example of tight fit. Because the tight-fit relation was depicted by one tight-fit containment event (the candle-in-cookie-cutter event) and one tight-fit support event (the turtle-on-pole event) and because the loose-fit test events were similarly depicted by one loose-fit support event (the peg-on-block) and one loose-fit containment event (the cup-in-bowl event), infants had to demonstrate the ability to generalize tight fit to both containment and support during the test phase. That is, it was not possible for infants to demonstrate the formation of an abstract category of tight fit without generalizing across both tight-fit containment and tight-fit support relations.

A sample of 12 native, adult Korean speakers confirmed that each tight-fit event would be described as *kkita* in Korean, whereas none of the loose-fit events would be described with this term. All events were filmed with a Sony digital video camera and then imported and edited on a Macintosh G4 computer so that they were all 6 s in length. The events were looped five times without pauses so that infants viewed five repetitions of the events within a 30-s trial.

Apparatus—The experiment was conducted in adjoining experimenter and infant rooms. In the 3 m × 3 m infant 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 22 cm under the monitor, was linked to a Panasonic video monitor in the adjoining experimenter room. This monitor allowed the experiment to record the duration of infants’ visual fixations during each trial. The monitor

also was 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 G5 and a specially designed program, Habit 2000 or Habit X (Cohen, Atkinson, & Chaput, 2000, 2004), to regulate the presentation of the visual and auditory events and to record infants' looking time during each trial.

Procedure—Infants were randomly assigned to one of the three conditions: silent, novel word, or familiar word, resulting in 6 male and 6 female infants in each condition. Parents were asked to complete the Locations and Places section of the MacArthur–Bates Communicative Development Inventory (CDI): Infants (Fenson et al., 1993) to provide some measure of the infants' spatial language comprehension and production. This section of the CDI asks about infants' comprehension and production of 11 spatial words, including terms such as *in*, *on*, *under*, and *below*.

The parent and infant were then taken to the testing room where the infant sat on the parent's lap, facing the color monitor. In the adjacent room, the experimenter started the testing session using the Habit program (Cohen et al., 2000, 2004). Infants then viewed an attention-getting stimulus, a green circle that chimed as it expanded and contracted. This attention getter was presented prior to the start of each trial to ensure that infants' attention was directed to the color monitor. Once infants looked at the monitor, the experimenter depressed a key on the control keyboard, which prompted the first habituation trial to start. The experimenter depressed and held down a second key on the control keyboard for as long as the infant watched the event on the monitor. Each trial lasted for as long as the infant watched the event (which could be the entire length of the trial, i.e., 30 s) or until the infant turned away from the event for more than 1 s continuously. Infants were required to look at an event for at least 2 continuous seconds in order for a look to be counted as a valid trial.

As the first trial, infants viewed a pretest event, a video of a pink pig being moved first to the left and then to the right by a hand. This event was presented to accustom infants to the room and the presentation of events on the monitor. Next, all infants were habituated to the same four dynamic tight-fit events: the candle placed *in* the cookie cutter, the peg placed *in* the block, the Duplo figure placed *on* the Duplo car, and the green Duplo block placed *on* the red Duplo block. Infants viewed these four habituation events in a semirandomized order across blocks of four trials until their total looking time during three consecutive trials was less than half of their total looking time during the first three habituation trials or until they viewed 20 habituation trials, whichever came first. Infants were then presented with the four test events.

All infants viewed the same four test events: the candle placed tightly *in* the cookie cutter in a tight-fit relation, the peg placed *on* the block in a novel loose-fit spatial relation, the turtle placed in a tight-fit relation on a pole and on top of two other turtles, and the cup placed loosely in the dog bowl. Although the familiar test event (the candle–cookie-cutter event) was always presented as the first test trial, the presentation order of the remaining three test events was counterbalanced across participants. To establish inter-observer reliability, we coded the looking times of a randomly chosen sample of 11 infants offline. The average correlation between online and offline looking time was .997 (range = .992–.999), indicating high interobserver reliability.

Results

Language development—The first set of analyses examined parental reports of the infants' spatial language development. A 3 (condition: silent vs. familiar word vs. novel word) \times 2 (sex: male vs. female) univariate analysis of variance (ANOVA) compared the number of spatial words comprehended by infants across conditions. Infants in the silent condition ($M = 8.25$ words, $SD = 3.28$ words), those in the familiar word condition ($M = 6.00$ words, $SD = 3.59$

words), and those in the novel word condition ($M = 8.25$ words, $SD = 3.28$ words) did not differ significantly in the number of spatial words they were reported to comprehend, $F(2, 30) = 1.84$, ns . Nor did infants in the various conditions differ significantly in the number of spatial words they were reported to produce ($M = 2.17$ words, $SD = 2.55$ words, for infants in the silent condition; $M = 2.75$ words, $SD = 3.31$ words, for infants in the familiar word condition; $M = 2.50$ words, $SD = 3.15$ words, for infants in the novel word condition; $F < 1$, ns). Thus, infants in each condition demonstrated equivalent levels of acquiring the spatial words listed on the Locations and Places section of the CDI. Because preliminary analyses failed to yield any significant effects or interactions of infants' acquisition of spatial language (either in the number of spatial words comprehended or produced or in their comprehension or production of the words *in* and *on*) with their looking times during the visual habituation task, infants' spatial language acquisition was not included among the variables in the analyses below.

Habituation phase—Listed in Table 2 are the means of infants' looking time in each condition to the average of the first three habituation trials and the four test trials. To ensure that infants did not meet the habituation criterion as an artifact, we compared infants' looking time during the average of the first three trials of habituation with their looking time during the familiar test event, which presented an event seen during habituation. Infants' looking times were examined in a 3 (condition) \times 2 (sex) \times 2 (trials: average of the first three habituation trials vs. familiar test) analysis of variance (ANOVA). The analysis yielded only a significant effect of trials, $F(1, 30) = 102.41$, $p < .001$, $\eta_p^2 = .77$. Infants looked significantly longer at the habituation events during the average of the first three habituation trials ($M = 28.31$ s, $SD = 8.92$ s) than at one of the same events presented as the familiar test event, the candle-in-cookie-cutter event ($M = 10.55$ s, $SD = 7.71$ s). There were no other significant effects or interactions. An additional analysis compared the number of habituation trials viewed by infants in each condition. The 3 (condition) \times 2 (sex) univariate ANOVA failed to reveal a significant difference in the number of habituation trials viewed among infants in the silent condition ($M = 9.00$, $SD = 3.73$), those in the familiar word condition ($M = 10.75$, $SD = 4.33$), and those in the novel word condition ($M = 10.75$, $SD = 2.99$), $F < 1$, ns . Thus, infants in the three conditions did not differ in their looking patterns during the habituation phase or in the number of habituation trials viewed.

Test phase—The next set of analyses examined whether infants formed the abstract categorical representation of the tight-fit spatial relation. Infants' looking times during the test trials were analyzed in a 3 (condition) \times 2 (sex) \times 2 (objects: familiar vs. novel) \times 2 (spatial relation: familiar vs. novel) mixed-model ANOVA. The analysis yielded a significant effect of objects, $F(1, 30) = 21.12$, $p < .001$, $\eta_p^2 = .41$. Infants looked significantly longer at the two test trials with novel objects ($M = 16.34$ s, $SD = 7.54$ s) than at the two test trials with familiar objects ($M = 11.24$ s, $SD = 7.54$ s). The analysis also yielded a significant Spatial Relation \times Condition interaction, $F(1, 30) = 5.94$, $p = .007$, $\eta_p^2 = .28$. The analysis yielded no other significant effects. To explore the source of the Spatial Relation \times Condition interaction, infants' looking times to the test events were analyzed separately by condition. Because there were no significant effects of sex, this variable was excluded from the remaining analyses.

For infants in the silent condition, a 2 (objects) \times 2 (spatial relation) ANOVA yielded only a significant effect of objects, $F(1, 11) = 14.62$, $p = .003$, $\eta_p^2 = .57$. As can be seen in the left-hand graph of Figure 2, infants in the silent condition looked significantly longer at the two test trials with novel objects ($M = 15.28$ s, $SD = 3.38$ s) than at the two test trials with familiar objects ($M = 9.22$ s, $SD = 5.64$ s). The analysis did not yield a significant effect of spatial relation ($F < 1$, ns), indicating that infants provided no evidence of discriminating between the familiar tight-fit and the novel loose-fit spatial relations in the events. Similarly, a 2 (objects) \times 2 (spatial

relation) ANOVA for infants in the novel word condition also yielded only a significant effect of objects, $F(1, 11) = 8.94, p = .01, \eta_p^2 = .45$, and no effect of spatial relation ($F < 1, ns$; see the middle graph of Figure 2). Infants in this condition looked significantly longer at the novel ($M = 17.40$ s, $SD = 7.76$ s) than the familiar objects ($M = 11.89$ s, $SD = 7.89$ s). Thus, infants who viewed the events in silence or heard the novel word during habituation provided evidence only of discriminating between the objects in the events and not of discriminating between the tight-fit and loose-fit spatial relations.

In contrast, for infants in the familiar word condition, a 2 (objects) \times 2 (spatial relation) ANOVA yielded only a significant effect of spatial relation, $F(1, 11) = 8.65, p = .01, \eta_p^2 = .44$. As can be seen in the right-hand graph of Figure 2, infants who heard the English word *tight* during habituation looked significantly longer at the two test trials with a novel loose-fit relation ($M = 18.22$ s, $SD = 8.92$ s) than at the two test trials with a familiar tight-fit relation ($M = 10.71$ s, $SD = 8.77$ s). The analysis did not yield a significant Objects \times Spatial Relation interaction ($F < 1, ns$). That is, infants in the familiar word condition demonstrated the same pattern of looking when the objects were familiar and when they were novel. Hence, infants in the familiar word condition responded in a manner consistent with forming the abstract categorical representation of tight fit.

Discussion

The results of Experiment 1 indicate that infants of 18 months can learn to form an abstract categorical representation of a tight-fit spatial relation if provided with an English term for the tight-fit relation during habituation. Specifically, infants who heard the word *tight* during habituation looked significantly longer at the test events with a novel loose-fit relation than at the test events with the familiar tight-fit relation, a pattern that did not differ with the familiarity or novelty of the objects depicting the relations. That is, these infants responded in a manner consistent with having formed an abstract categorical representation of tight fit. In contrast, infants who heard the phrases with a novel word (i.e., “She puts it toke”) during habituation and those who viewed the events in silence did not form the abstract spatial category. In fact, these infants did not provide any evidence of attending to the tight-fit relation in the events and instead only increased their looking times to test events that presented novel objects, regardless of whether the spatial relation between those objects was the familiarized tight-fit relation or the novel loose-fit relation.

The contrasting results across conditions suggest that using an English term with which infants may have had previous experience can facilitate infants’ spatial categorization of the tight-fit relation. Unfortunately, parents of the infants in Experiment 1 were not asked about their infants’ comprehension of the word *tight* (this question was asked of the informal sample of parents who were initially queried during the design of the study). A second, separate sample of parents of 18-month-old infants did not believe their infant comprehended the word *tight*, suggesting that infants in the familiar word condition also did not comprehend the term. However, those parents who were asked about their infants’ comprehension of the word *tight* noted that their infant did have some experience with the word. Given that the term was presented in a minimally informative syntactic frame (i.e., “it goes tight”), infants would have had difficulty pinpointing the meaning of the term from the syntactic context. That is, the results from the familiar word condition suggest that infants were sufficiently familiar with the term that their attention was directed to the tight-fit relation, thus facilitating their ability to form the abstract spatial category of tight fit. However, the results cannot disambiguate if infants’ experience with the term was limited to its sound form or also included its meaning. Thus, some familiarity with a particular English term, whether with the sound form or its meaning, appeared to facilitate infants’ spatial categorization of the tight-fit relation.

Interestingly, infants who heard the novel word during habituation did not yield the same set of findings as those who heard the familiar word, suggesting that a previously experienced word, but not a novel word, can facilitate 18-month-old infants' categorization of a tight-fit relation. Although the same novel word and phrases were used in a previous study in which 18-month-old infants successfully formed an abstract categorical representation of support (Casasola & Bhagwat, 2007), infants in the present study did not benefit from the presentation of the novel word. Thus, infants of 18 months can use "She puts it toke" to facilitate their spatial categorization if the spatial relation is that of support, but not if the relation is that of tight fit. Possibly, the unfamiliarity of the spatial grouping along with the unfamiliarity of the novel word made it especially challenging for infants to process the novel word and then use it to facilitate their categorization of the tight-fit relation. Thus, despite presenting the novel word in a richer syntactic context than the English term *tight*, infants did not appear to benefit from the pairing of the novel word with each example of tight fit during the habituation phase. In contrast, infants may have had sufficient experience with the term *tight* so that the sound form was not unfamiliar, or perhaps as it referred to the relation between objects, the familiarity of the word may have reduced the processing load of the label and allowed infants to use the specific label to facilitate their categorization of the tight-fit relation. If this possibility is correct, then providing infants with additional experience with the novel word as referring to tight-fit relations should result in the novel word aiding infants in forming an abstract categorical representation of tight fit. Experiment 2 was conducted to explore this possibility.

Experiment 2

The second experiment explored whether infants of 18 months could learn to form an abstract categorical representation of a tight-fit spatial relation if given additional experience with a novel label for this relation. Infants sat with an experimenter who demonstrated a tight-fit relation between two different sets of objects while labeling the relation with the novel word *toke*. One pair of objects depicted a support tight-fit relation, whereas the other depicted a containment tight-fit relation. We hypothesized that hearing the novel word applied to a tight-fit containment and a tight-fit support event would lead infants to note the relational commonality between these two events. To ensure that infants were sufficiently attentive to the tight-fit relations, the experimenter invited them to place the objects "toke" themselves. The experimenter then applauded enthusiastically and provided the novel word again when the child joined the objects into their tight-fit relation. It was expected that the experience of producing the tight-fit relations and hearing a novel label for these relations would provide infants with sufficient experience with the novel word as well as the tight-fit relations to facilitate their ability to form the spatial category in the habituation task.

Following this interaction, infants were tested in the visual habituation task from Experiment 1. Infants were randomly assigned to a silent or a novel word condition. If experience in viewing and producing tight-fit relations while hearing them labeled is sufficient to facilitate infants' attention to the common tight-fit relation between spatial events, then they should form an abstract categorical representation of tight-fit, even when viewing the events in silence during habituation. In contrast, if the firsthand experience simply provides infants with the needed previous experience so that both the tight-fit relations and the novel word are not as unfamiliar, then infants may still require hearing the novel word during habituation to form the abstract spatial category of tight fit. In sum, the two conditions were included to explore the online effects of hearing a novel word (i.e., during habituation) as well as the possible long-term effects of hearing the novel word during their firsthand experience with the experimenter.

Method

Participants—The final sample consisted of 30 English-language learning infants of 18 months ($M = 17.89$ months, $SD = 1.01$ months), of whom 17 were female and 13 were male.

Infants were recruited in the same manner as in Experiment 1. None of the infants who participated in Experiment 1 were recruited for Experiment 2. Infants were from predominately middle-class Caucasian families, and all infants were learning only English. Two additional infants participated but were not included in the final sample because these infants became too inattentive to complete the visual habituation task. All participants were given a T-shirt, spill-proof cup, or bib in appreciation of their participation.

Stimuli—The stimuli for the habituation and test phases were the same as those in the silent and novel word conditions of Experiment 1. For the training session, two pairs of objects were selected that each depicted a tight-fit relation. One pair illustrated a containment relation (the green peg placed in a plastic yellow block) and was presented as an event on video during the habituation task. The other object pair illustrated a support relation (a purple rectangular Mega blok onto which a white Mega blok chicken could be placed in a tight-fit relation), an event that was not seen by infants during the habituation task. An independent sample of six native Korean adults confirmed that each of these events would be described as *kkita*.

Apparatus—The training session was conducted in a 12 m × 10 m room that contained three child-size chairs set around a child-size table (66 cm × 66 cm × 54 cm) and a Canon ZR80 digital video camera, 45 cm from the table. The apparatus used in the habituation task was identical to that described in Experiment 1.

Procedure—For the training session, infants and their parent were taken to a room with the child-size table and camera. Infants sat at the table with the experimenter while the parent was seated next to the child and completed the Location and Places section of the CDI. Parents were instructed to not interact with their child during the training session. The experimenter counterbalanced whether the tight-fit support or the tight-fit containment event was shown first. Each training session began with the experimenter demonstrating one of the tight-fit relations, pressing down with effort to highlight the tight-fit relation that resulted. Prior to joining the objects, the experimenter told the child, “Watch. I am going to put this *toke*.” Once the experimenter produced this action, she again provided the novel label, “Look, I put it *toke*!” Next, the experimenter asked the child “Should I put it *toke* again?” and then repeated the action, again labeling the tight-fit relation with the novel word. The experimenter then asked the infants to produce the tight-fit relation, using the novel word: “Will you put it *toke*?” If infants successfully produced the relation by joining the objects together, the experimenter clapped excitedly and said “Good! You put it *toke*!” and asked the infant to do it again. If the infant was not able to accomplish the action, the experimenter gently guided the infant’s hand or held the referent object steady while the infant joined the objects into a tight-fit relation. The experimenter then praised the child, using the novel word. This sequence was repeated with a second pair of objects after the first pair of objects was removed. In total, infants heard the novel word *toke* approximately 16 times.

Following this training session, infants were taken across the hall and participated in the visual habituation task from Experiment 1. The procedure for the habituation study was identical to that described in Experiment 1, with the following exceptions. Infants were randomly assigned to a novel word or a silent condition, resulting in 9 female and 6 male infants in the novel word condition and 8 female and 7 male infants in the silent condition. To establish interobserver reliability, the looking times of 6 randomly chosen infants were coded offline. The average correlation between online and offline looking time was .999 (range = .998–.999), indicating high interobserver reliability.

Results

Language development—The first set of analyses explored infants' comprehension and production of spatial language, as reported by parents on the Location and Places section of the CDI. A 2 (condition: silent vs. novel word) \times 2 (sex: male vs. female) univariate ANOVA on the number of spatial words comprehended did not yield any significant effects. Infants in the silent condition ($M = 7.46$ words, $SD = 2.37$ words) did not differ from those in the novel word condition ($M = 7.33$ words, $SD = 2.08$ words) on their comprehension of spatial words (F ns). Nor did infants in each condition differ significantly in the number of spatial words they were reported to produce ($F < 1$, ns; $M = 1.92$ words, $SD = 2.02$ words, for infants in the silent condition, and $M = 3.00$ words, $SD = 2.65$ words, for infants in the novel word condition).

Habituation phase—Listed in Table 3 are the averaged looking times to the first three habituation trials as well as the means of infants' looking times to each of the four test trials in each condition. An analysis was conducted to ensure that infants demonstrated a significant decrease in looking time from the beginning of the habituation phase to the test phase. A 2 (condition: silent vs. novel word) \times 2 (sex: male vs. female) \times 2 (trials: average of the first three habituation trials vs. familiar test trial) mixed-model ANOVA yielded a significant effect of trials, $F(1, 26) = 252.24$, $p < .001$, $\eta_p^2 = .91$, as well as a significant Trials \times Condition interaction, $F(1, 26) = 6.74$, $p = .01$, $\eta_p^2 = .21$, and a significant Sex \times Trials interaction, $F(1, 26) = 8.71$, $p = .007$, $\eta_p^2 = .25$. Although infants in both conditions demonstrated a significant decrease in looking time from the beginning of habituation to the familiar test event, this decrease was greater for infants in the silent condition ($M = 25.71$ s, $SD = 4.24$ s vs. $M = 8.06$ s, $SD = 7.66$ s) than for infants in the novel word condition ($M = 22.21$ s, $SD = 7.11$ s vs. $M = 9.77$ s, $SD = 4.33$ s), yielding the ordinal interaction of condition and trials. Similarly, the Sex \times Trials significant interaction was attributed to male infants' demonstrating a greater decrease in looking time from the beginning of habituation ($M = 24.87$ s, $SD = 5.20$ s) to the familiar test trial ($M = 6.39$ s, $SD = 4.29$ s) than female infants ($M = 23.27$ s, $SD = 6.65$ s and $M = 10.85$ s, $SD = 6.80$ s, respectively). Despite these ordinal interactions, the results indicate that infants across both conditions and sexes decreased their looking time from habituation to the familiar test event.

Interestingly, a 2 (condition) \times 2 (sex) univariate ANOVA comparing the number of habituation trials viewed by infants in each condition yielded a significant effect of condition, $F(1, 26) = 10.12$, $p = .004$, $\eta_p^2 = .28$. Infants in the silent condition viewed significantly more habituation trials ($M = 11.60$, $SD = 3.38$) than did infants in the novel word condition ($M = 7.80$, $SD = 2.73$), indicating that infants in the silent condition took more trials to meet the habituation criterion than infants in the novel word condition.

Test phase—The next analysis examined whether infants formed the abstract categorical representation of tight fit and whether this ability varied across the silent and novel word conditions. Infants' looking times were examined in a 2 (condition) \times 2 (sex) \times 2 (objects: familiar vs. novel) \times 2 (spatial relation: familiar vs. novel) mixed-model ANOVA. The analysis yielded a significant effect of objects, $F(1, 26) = 22.83$, $p = .001$, $\eta_p^2 = .47$, as well as a significant effect of spatial relation, $F(1, 26) = 6.77$, $p = .02$, $\eta_p^2 = .21$. Infants looked significantly longer at the two test trials with novel objects ($M = 18.52$ s, $SD = 8.77$ s) than at the two test trials with familiar objects ($M = 11.26$ s, $SD = 7.43$ s). Likewise, infants looked significantly longer at the two test trials with a novel loose-fit spatial relation ($M = 16.32$ s, $SD = 8.88$ s) than at the two test trials with the familiar tight-fit relation ($M = 13.45$ s, $SD = 7.33$ s). The analysis also yielded a marginally significant Condition \times Spatial Relation interaction, $F(1, 26) = 3.91$, $p = .059$, $\eta_p^2 = .13$. The analysis did not yield any other significant effects. Although the Condition

× Spatial Relation interaction was only marginally significant, it did suggest that infants' looking times across the two conditions differed somewhat. For this reason, infants' looking times to the test trials was analyzed separately by condition. Because there were no significant effects of sex, this variable was excluded from the analyses reported below.

For infants in the silent condition, a 2 (objects) × 2 (spatial relation) ANOVA yielded a significant effect of objects, $F(1, 14) = 10.79, p = .005, \eta_p^2 = .44$. Infants looked significantly longer at the two test trials with novel objects ($M = 18.21$ s, $SD = 8.85$ s) than at the two test trials with familiar objects ($M = 10.36$ s, $SD = 8.85$ s). The analysis also yielded a significant Objects × Spatial Relation interaction, $F(1, 14) = 4.58, p = .05, \eta_p^2 = .25$. As can be seen in the left-hand graph of Figure 3, infants looked longer at the novel loose-fit than familiar tight-fit relation when the objects were familiar but not when the objects were novel. Thus, infants provided evidence of discriminating the change in spatial relation but no evidence of having formed the abstract spatial category of tight fit.

For infants in the novel word condition, a 2 (objects) × 2 (spatial relation) ANOVA yielded a significant effect of objects, $F(1, 14) = 13.76, p = .002, \eta_p^2 = .50$, as well as a significant effect of spatial relation, $F(1, 14) = 8.15, p = .01, \eta_p^2 = .37$. Infants looked significantly longer at the two test trials with novel objects ($M = 18.83$ s, $SD = 8.20$ s) than at the two test trials with familiar objects ($M = 12.12$ s, $SD = 5.83$ s). They also looked significantly longer at the two test trials with a novel spatial relation ($M = 18.06$ s, $SD = 8.47$ s) than at the two test trials with a familiar spatial relation ($M = 12.89$ s, $SD = 5.56$ s). The analysis did not yield a significant Objects × Spatial Relation interaction ($F < 1, ns$), indicating that the pattern of infants' looking to the familiar versus novel relation was the same for familiar and novel objects. That is, infants responded in a manner consistent with having formed the abstract categorical representation of tight fit, looking longer at the novel than at the familiar relation regardless of object familiarity or novelty (see the right-hand graph of Figure 3).

To explore the effect of the training on infants' categorization of the tight-fit relation, we conducted an additional set of analyses that compared infants in the silent and novel word conditions when given the training with the experimenter (Experiment 2) versus when simply viewing the events for the first time during habituation (Experiment 1). A 2 (training: yes vs. no) × 2 (condition: silent vs. novel word) × 2 (objects) × 2 (spatial relation) ANOVA yielded two significant effects and one marginally significant effect. First, infants looked significantly longer at the two test trials with novel objects than at the two test trials with familiar objects, $F(1, 50) = 42.72, p < .001, \eta_p^2 = .46$. Second, there was a significant Training × Spatial Relation interaction, $F(1, 50) = 5.63, p = .02, \eta_p^2 = .10$, indicating that infants who participated in the training (i.e., those in Experiment 2) performed differently than those who did not (i.e., infants in Experiment 1). Finally, there was a marginally significant three-way interaction of training, condition, and spatial relation, $F(1, 50) = 3.80, p = .057, \eta_p^2 = .07$, suggesting that infants' performance in the task varied not only as a function of the training (Experiment 1 vs. Experiment 2) but also as a function of the condition (hearing the novel word vs. viewing the events in silence).

Follow-up analyses examined infants' looking times to the test events separately by condition, but including training as a between-subjects variable. For infants in the silent condition, a 2 (training) × 2 (objects) × 2 (spatial relation) ANOVA yielded a significant effect of objects, $F(1, 25) = 21.09, p = .001, \eta_p^2 = .46$, and a marginally significant Training × Objects × Spatial Relation interaction, $F(1, 25) = 3.47, p = .07, \eta_p^2 = .12$. The interaction approached significance because infants who participated in the training (i.e., those in Experiment 2) looked longer at

the novel loose-fit relation than at the familiar tight-fit relation when familiar objects depicted the relations, whereas those who did not receive the training (i.e., infants in Experiment 1) failed to make this discrimination.

For infants in the novel word condition, a 2 (training) \times 2 (objects) \times 2 (spatial relation) ANOVA yielded a significant effect of objects, $F(1, 25) = 21.93, p = .001, \eta_p^2 = .47$, and a significant Spatial Relation \times Training interaction, $F(1, 25) = 6.27, p = .02, \eta_p^2 = .20$. The significant Spatial Relation \times Training interaction resulted because only infants who received the training provided evidence of forming the abstract categorical representation of tight fit, whereas those who did not receive the training failed to look longer at the novel loose-fit relation relative to the familiar tight-fit relation. In addition, a comparison of the infants in the novel word condition of Experiment 2 with infants in the familiar word condition of Experiment 1 failed to yield any significant differences as a function of condition. A 2 (condition: familiar word vs. novel word) \times 2 (objects) \times 2 (spatial relation) ANOVA yielded a significant effect of objects, $F(1, 25) = 14.48, p < .001, \eta_p^2 = .37$, and spatial relation, $F(1, 25) = 17.29, p < .0001, \eta_p^2 = .41$, but no significant effects or interactions with condition (all F s $< 1, ns$). In sum, infants who received the training with the experimenter and then were provided with the novel word during habituation were similar to infants who heard the familiar word in Experiment 1 and distinct from infants in Experiment 1 who were given the novel word without first being familiarized to this unfamiliar word in a training session.

In an attempt to disambiguate the effect of label familiarity from the first-hand experience of the two tight-fit relations, in a final analysis we compared the looking time of infants in the familiar word condition of Experiment 1 with those of infants in the silent condition of Experiment 2. A 2 (condition: familiar word vs. silent) \times 2 objects \times 2 spatial relation ANOVA yielded a significant effect of the objects, $F(1, 25) = 12.63, p < .002, \eta_p^2 = .34$, and the spatial relation, $F(1, 25) = 9.30, p = .005, \eta_p^2 = .27$, as well as a significant Spatial Relation \times Condition interaction, $F(1, 25) = 6.81, p = .02, \eta_p^2 = .21$. The significant interaction indicates that a possibly familiar English term (i.e., *tight*) presented during habituation was more effective in facilitating infants' spatial categorization than viewing the habituation events in silence following the firsthand experience with the novel label and tight-fit relations. That is, whereas the training did aid infants in attending to the tight-fit relation during the habituation task, this facilitative effect was not as great as presenting an English term during the habituation task itself.

Discussion

The results from Experiment 2 indicate that as a group, infants in this second experiment looked significantly longer at the two test trials with the novel loose-fit relation than at the two test trials with the familiar tight-fit relation. In addition, when the results from Experiment 2 were compared with those of the infants in the silent and novel word conditions of Experiment 1, we found that the results yielded a significant effect of training. Thus, as a group, infants in both the novel word and silent conditions benefited from viewing and producing tight-fit relations while an experimenter labeled the resulting relation with a novel word. Given this firsthand experience, infants performed significantly better on the subsequent visual habituation task. Thus, the additional exposure to the novel word and, quite possibly, the experience of viewing and producing firsthand the tight-fit relation, with two sets of objects, resulted in an increased sensitivity to the tight-fit relation when presented on video and in a visual habituation task.

However, an inspection of Figure 3 and the marginal Condition \times Spatial Relation interaction for infants in Experiment 2, suggests that the training was more effective for infants in the

novel word condition than for those in the silent condition. Infants who heard the novel word again during the habituation phase viewed significantly fewer habituation trials than did infants in the silent condition, suggesting that the novel word facilitated infants' processing of the spatial events. In addition, when the results from the two conditions were analyzed separately, only infants in the novel word condition formed an abstract categorical representation of tight fit. Infants in the silent condition provided evidence of discriminating between a tight fit and a loose fit relation with familiar objects but no evidence of generalizing this relation to a new example of the relation. Hence, the training was not sufficiently effective to aid infants in forming the abstract spatial category of tight fit in the habituation task when infants viewed the events in silence during habituation. Rather, infants required hearing the novel word both during the training and during the habituation phase in order to form the abstract categorical representation of tight fit.

General Discussion

The present two experiments explored 18-month-old infants' ability to form an abstract categorical representation of tight-fit spatial relations. During habituation, infants viewed both tight-fit containment and tight-fit support relations. To form the spatial category, infants had to focus on the common relation of tight-fit while disregarding the distinction between containment and support relations in the tight-fit events. Because most infants in the present studies comprehended the spatial words *in* and *on*, they were sensitive to the distinction between containment and support. Disregarding this semantically relevant distinction in favor of a spatial relation that is not described in English proved challenging for them. In both experiments, infants who viewed the events in silence failed to form the abstract categorical representation of tight fit. Infants in Experiment 1 who heard a novel spatial word during habituation also failed to form the tight-fit spatial category. Rather, it was only infants who heard the English term *tight* or, in the case of the second experiment, those who were given experience with a novel label as referring to the tight-fit relation, who learned to form the abstract categorical representation of tight fit. Thus, the two experiments provided evidence for a facilitative effect of a label on 18-month-old infants' categorization of tight fit but showed that this facilitative effect depended on whether infants had had some previous experience with the label.

Although we had hypothesized that the English term *tight* might be more effective in facilitating infants' spatial categorization than a novel word, it was somewhat surprising that infants in Experiment 1 who heard the novel word did not form the spatial category. The first reason why this finding was unexpected is that many infants of 18 months are reported to not yet comprehend the word *tight*, although many have had some experience hearing the term, resulting in familiarity with the sound form of the word. Thus, the "familiar" word may not have been highly familiar in meaning to infants. Second, a recent study by Casasola and Bhagwat (2007) used the same novel word *toke*, presented in the same phrases as in the present experiments, and found that the novel word facilitated 18-month-old infants' categorization of a support relation (i.e., placing one object *on* another). However, these infants were tested with a spatial category consistent with the English semantic category of "on." Perhaps because the spatial category in the present experiments was unfamiliar and because infants lacked previous experience with a single label being used to describe both tight-fit containment and tight-fit support, the novel word did not facilitate infants' categorization of the tight-fit relations in Experiment 1. Rather, infants first required experience with the novel word as referring to the tight-fit events, as in Experiment 2, in order for the label to facilitate their spatial categorization. Perhaps the sociopragmatic information afforded in the interaction with another individual might have provided additional cues signaling that the novel word referred to the tight-fit relation. In particular, experiencing a live demonstration where the same word was applied to both the tight-fit containment and the tight-fit support event might have played a critical role

in directing infants' attention to the tight-fit relational commonality in the containment and support events. Consequently, when infants again heard the novel word in the habituation task, they were able to direct their attention to the tight-fit relation and form the abstract spatial category of tight fit.

Nonetheless, it remains unclear exactly what element (or combination of elements) of the training session in Experiment 2 facilitated infants' ability to form the spatial category of tight fit when hearing the novel word in the habituation task. As noted, viewing the experimenter label each tight-fit event—one being a containment relation and one, a support relation—might have highlighted the tight-fit relation, in addition to cueing infants that the novel word referred to this relation. Infants also may have benefited from viewing the tight-fit events first-hand, perhaps noticing perceptual features of the tight-fit relation that might not have been apparent in the videotaped events. In particular, infants' production of the tight-fit relation as an experimenter labeled it might have been especially effective in leading infants to then form the spatial category in the habituation task. Several studies have noted that infants are most attuned to those actions that they themselves produce, learning to label these actions prior to extending them to actions produced by others (Huttenlocher, Smiley, & Charney, 1983). Similarly, experience with producing actions influences how infants interpret others' actions (Sommerville, Woodward, & Needham, 2005), their preference in viewing the actions of others (Hauf, Aschersleben, & Prinz, 2007), and their ability to generalize actions to new objects in an imitation paradigm after a 24-hr delay (Hayne, Barr, & Herbert, 2003). Possibly, then, providing infants with the opportunity to produce the tight-fit relations enhanced their attention to the tight-fit relation. A particularly powerful combination might have occurred in providing the novel label when infants had produced the action themselves and, thus, were attentive to the action of placing one object in a tight-fit relation with another object.

Yet another possibility, and one that does not rule out the possibilities above, is that simply providing infants with more experience with the novel word prior to hearing it during the habituation task might have sufficiently reduced the processing load to allow infants to attend both to the novel word and to the tight-fit relation in the novel word condition of the habituation task. That is, simply gaining exposure to the sound form of a word, without necessarily acquiring a sense of its meaning, may have been sufficient to facilitate infants' categorization of the tight-fit relation. Indeed, consistent with this possibility, Robinson and Sloutsky (2007) showed that auditory overshadowing of visual processing occurs only with novel words but not familiar words, presumably because the novel words demand more attention and inhibit infants' processing of the visual input. The processing explanation may account for the difference in results across the familiar and novel word conditions in Experiment 1. First, the novel word was completely unfamiliar to infants and, hence, may have required additional attention. Second, the phrases with the familiar word were shorter in length, requiring less time to process, than the phrases with the novel word. Although the novel word was presented in a richer syntactic context and with a familiar verb (*put*), this additional context might not have been as helpful as a word that made reference to the type of relation depicted or, perhaps, one that had been heard previously. Thus, one reason why a familiar label (either one that infants have heard prior to participating in the study or one to which infants are familiarized in the course of the study) might result in infants forming the spatial category may have to do with their ability to attend to the label presented and its reference to the spatial relation in a dynamic event.

The present two experiments cannot disambiguate which of the possibilities outlined above resulted in infants learning to form the abstract categorical representation of tight fit when hearing the English term *tight* in Experiment 1 and the novel word *toke* following exposure to this term in Experiment 2. Rather, the present two experiments represent an initial investigation into how a specific label and infants' familiarity with the label may facilitate the types of spatial

categories that infants can learn to form. Given the rich range of cues that infants could have used in the training of Experiment 2, a number of additional experiments are needed to begin to refine which of these cues, or combination of cues, resulted in the training's beneficial effect on infants' ability to form an abstract categorical representation of tight fit. Although the training seemed most effective when infants were presented with the novel word a second time during habituation, this is not to say that the training had no effect for infants in the silent condition. Following the training, these infants demonstrated the ability to discriminate between novel and familiar spatial relations when the objects were familiar, a discrimination not made by infants in the silent condition of Experiment 1. Thus, infants in each condition of Experiment 2 demonstrated more advanced processing of the events than infants in the analogous conditions of Experiment 1. The stronger performance of the infants in the novel word condition of Experiment 2 relative to those in the silent condition of Experiment 2 suggests that labels can give a potentially powerful boost when presented in conjunction with the spatial relation to which they refer. That is, the effect of labels appears strongest online (when presented with the spatial relation) rather than offline (when presented prior to the visual habituation task only). In addition, infants presented with the English term *tight* in Experiment 1 performed significantly better on the habituation task than infants in the silent condition of Experiment 2, suggesting that an existing English label facilitates infants' spatial categorization more than does the training by itself. However, it is important to recognize that the effect of the training may have been dampened by changing the context in which the novel label was introduced in person and by testing infants on their formation of the spatial categorization in a visual habituation task that presented the events on video.

In sum, the results from the two experiments contribute to the growing evidence of ways in which a specific label can facilitate infants' ability to form groupings of spatial events that they may not otherwise form (Casasola, 2005a; Casasola & Bhagwat, 2007). Granted, young infants of 5 months can generalize a tight-fit support relation to a tight-fit containment relation with simple objects that are perceptually similar (Hespos & Spelke, 2004). However, when the objects are more complex and perceptually distinct, neither infants of 10 months nor those of 18 months generalize from a set of more varied tight-fit events to a new example of tight fit (Casasola & Cohen, 2002). Greater heterogeneity among spatial events appears to require support from language to a degree that more homogeneous spatial categories do not. It may also be that for infants of 18 months, who have begun to acquire the semantic spatial categories of "in" and "on," a label for the tight-fit relation is especially important in directing their attention to the distinction between tight-fit versus loose-fit rather than the more familiar distinction between containment versus support. Choi (2006) demonstrated that English-language learning toddlers who were producing the word *in* were less sensitive to the tight-fit relation than were English-language learning toddlers without this term in their spatial vocabulary or Korean toddlers of the same age. Similarly, Casasola (2006) found that Korean-language learning 18-month-olds could form the spatial category of tight fit when tested with the same task as infants in the silent condition of Experiment 1 although they did not form a spatial category of containment.

Together, these findings suggest that experience with spatial language might begin to alter preverbal sensitivities as early as infants' second year. As the results of Experiment 2 suggest, there can be a carryover effect both of a label and of the experience of viewing and producing tight-fit relations (i.e., from the training with the experimenter to the habituation task) and an online effect of a label (i.e., when presented during that habituation phase of the study). What remains to be better understood is how much real-world experience with spatial language is required for infants to form a particular spatial category without the need to hear the spatial word when viewing the spatial relation. An equally important question is how spatial language can begin to bolster other types of experiences, such as infants' own experiences in observing

and producing spatial relations, in shaping the types of abstract categorical representations that infants learn to form.

Acknowledgments

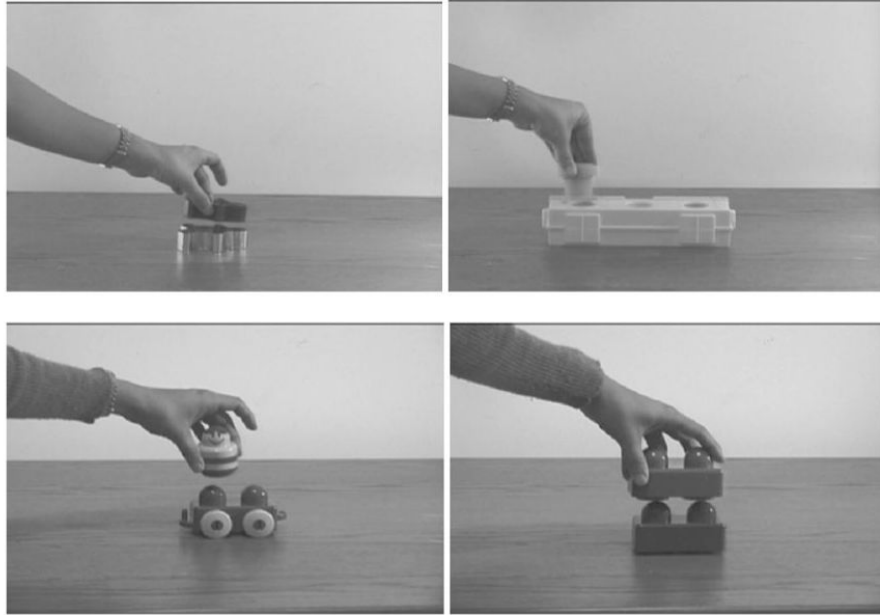
This research was funded by a grant from the National Science Foundation (PECASE BCS-0349183), an R03 grant from the National Institute of Health (HD43941-01), and a Hatch award from the College of Human Ecology, Cornell University. Anne S. Burke conducted a portion of Experiment 2 as an undergraduate honors thesis. We thank Kristen Pallonetti, Hannah Choi, and Christen Kisch at the Cornell Infant Studies Laboratory for their assistance in participant recruitment and data collection. We extend our sincere thanks to the parents and infants who generously gave of their time to participate in this research.

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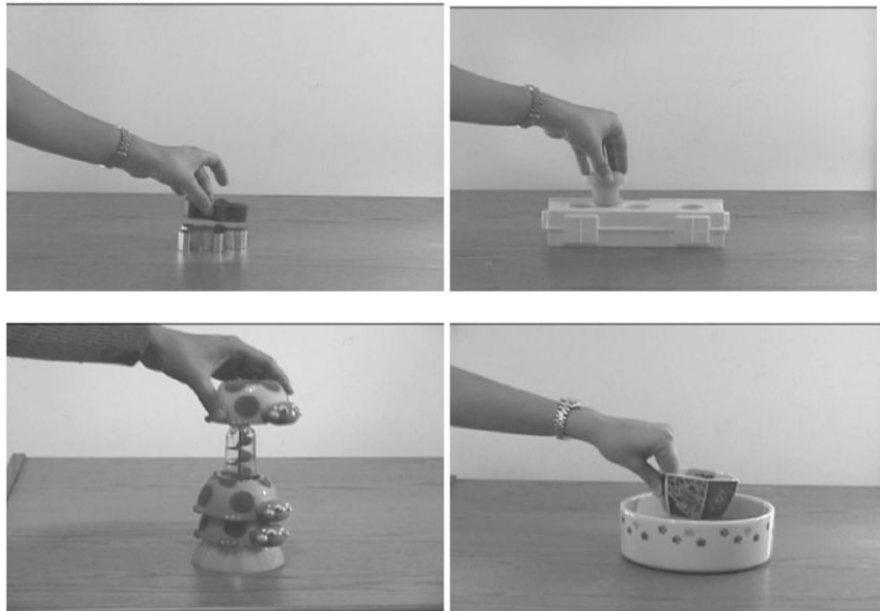
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Habituation Events:



Test Events:

**Figure 1.**

The middle frame of the four dynamic, tight-fit habituation events (top two rows) and the four test events (bottom two rows) presented to infants in Experiments 1 and 2.

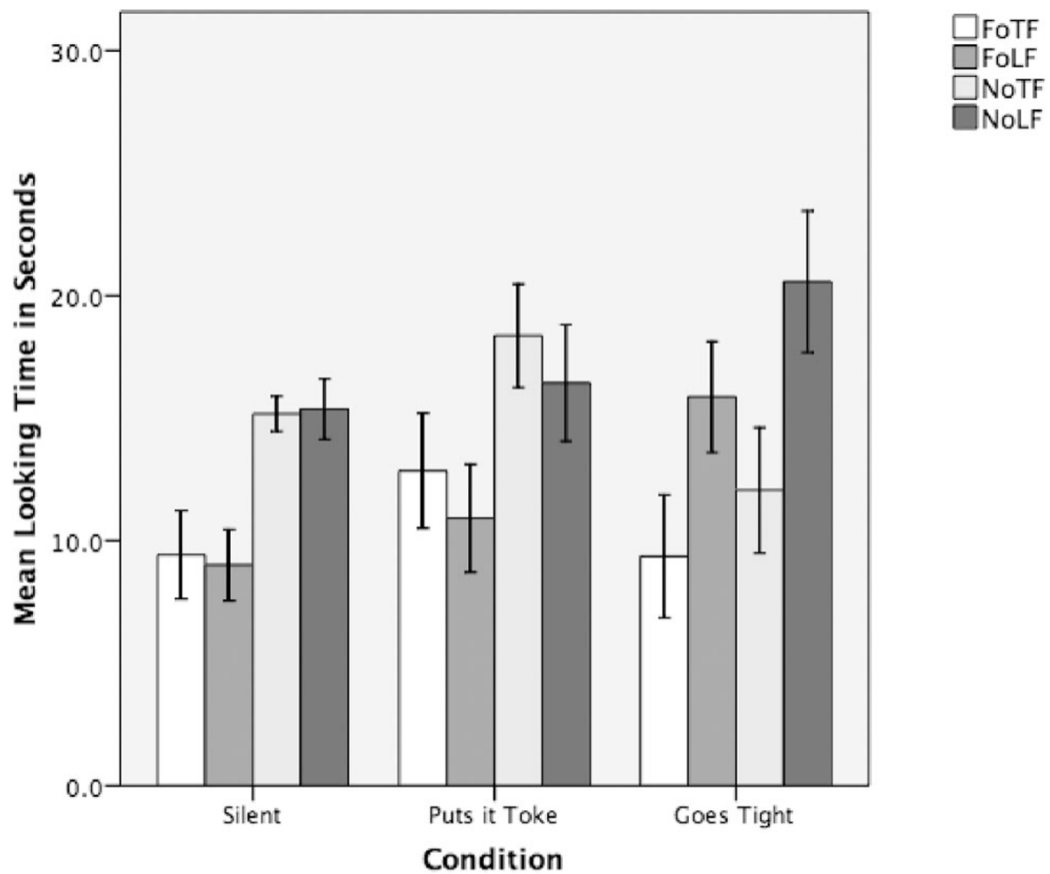


Figure 2. For infants in Experiment 1, their looking times in seconds (with standard error) in each condition to the familiar tight-fit relation (TF) versus the novel loose-fit relation (LF) when the objects were familiar (Fo) and when they were novel (No). Error bars represent ± 1 standard error of the mean.

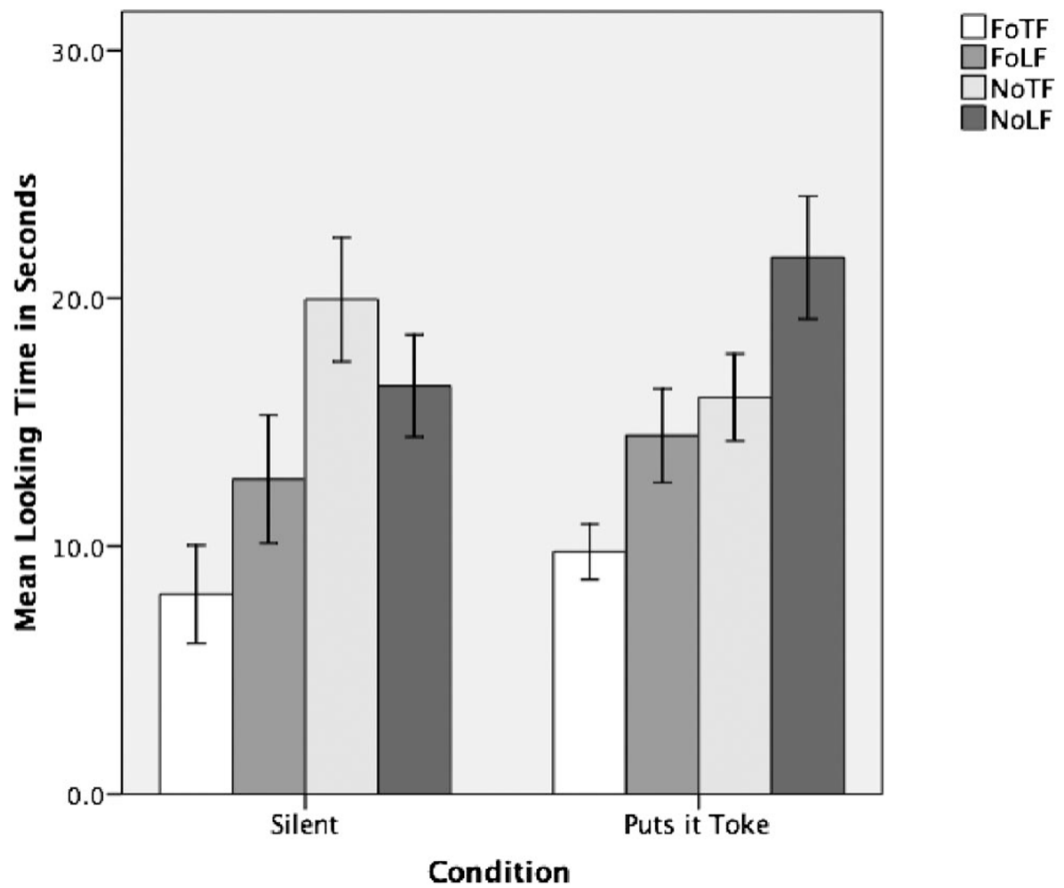


Figure 3.

For infants in Experiment 2, their looking times in seconds (with standard error) in the silent versus novel word condition to the familiar tight-fit relation (TF) versus the novel loose-fit relation (LF) when the objects were familiar (Fo) and when they were novel (No). Error bars represent ± 1 standard error of the mean.

Table 1

Auditory Input Presented to Infants in the Two Word Conditions During the Habituation Phase of Experiment 1

Familiar word condition	Novel word condition
“Look! ... It goes tight”	“Look! ... She puts it toke”
“Wow! ... Goes tight.”	“Wow! ... She put it toke!”
“Tight”	“She puts it toke”
“Look! ... It goes tight”	“Look! ... She puts it toke”
“See? ... Goes tight.”	“See? ... She put it toke!”

Table 2

Mean Looking Time in Seconds (With Standard Deviation) of Infants in Each Condition of Experiment 1 to the Average of the First Three Habituation Trials and Each Test Trial

Habituation condition	Silent	Familiar word	Novel word
Average of first three habituation trials	23.68 s (5.36 s)	27.72 s (5.69 s)	33.54 s (11.76 s)
Familiar objects in a tight fit	9.43 s (6.24 s)	9.37 s (8.67 s)	12.86 s (8.13 s)
Familiar objects in a loose fit	9.01 s (5.04 s)	15.87 s (7.82 s)	10.92 s (7.64 s)
Novel objects in a tight fit	15.18 s (2.48 s)	12.06 s (8.88 s)	18.37 s (7.31 s)
Novel objects in a loose fit	15.38 s (4.29 s)	20.57 s (10.02 s)	16.44 s (8.20 s)

Table 3

Mean Looking Time in Seconds (With Standard Deviation) of Infants in Each Condition of Experiment 2 to the Average of the First Three Trials of Habituation and Each Test Trial

Habituation condition	Habituation condition	
	Silent	Novel word
Average of first three habituation trials	25.71 s (4.24 s)	22.21 s (7.11 s)
Familiar objects in a tight fit	8.06 s (7.66 s)	9.77 s (4.33 s)
Familiar objects in a loose fit	12.71 s (10.03 s)	14.47 s (7.32 s)
Novel objects in a tight fit	19.95 s (9.70 s)	16.01 s (6.79 s)
Novel objects in a loose fit	16.47 s (7.99 s)	21.65 s (9.61 s)