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Do Novel Words Facilitate 18-Month-Olds' Spatial Categorization?

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Abstract

Eighteen-month-olds' spatial categorization was tested when hearing a novel spatial word. Infants formed an abstract categorical representation of support (i.e., placing 1 object *on* another) when hearing a novel spatial particle during habituation but not when viewing the events in silence. Infants with a productive spatial vocabulary did not discriminate the support relation when hearing the same novel word as a count noun. However, infants who were not yet producing spatial words did attend to the support relation when presented with the novel count noun. The results indicate that 18-month-olds can use a novel particle (possibly assisted by a familiar verb) to facilitate their spatial categorization but that the specificity of this effect varies with infants' acquisition of spatial language.

The relation between thought and language in early development continues to be a topic of debate, long after Piaget (Piaget & Inhelder, 1967) originally argued that language mapped onto infants' existing concepts and Vygotsky (1962) proposed that language played an active role in the development of children's concepts. This debate remains relevant to our current understanding of cognitive development, and several decades later, researchers are still exploring and debating the interaction between cognition and language in development. Although advances in cognitive development have been linked to milestones in language development (Gopnik & Choi, 1990; Gopnik, Choi, & Baumberger, 1996; Gopnik & Meltzoff, 1986, 1987, 1992), it is also the case that experience with specific labels has been shown to facilitate infants' abilities to form categories of objects (e.g., Balaban & Waxman, 1997; Booth & Waxman, 2002, 2003; Waxman & Booth, 2001, 2003). The present investigation further explored how cognition and language may interact during infants' second year but focused on the domain of space. Specifically, in the present experiment, we explored whether infants of 18 months are sufficiently familiar with the syntactic frames that signal a spatial relation to attend to and facilitate their formation of an abstract spatial category of support when hearing a novel spatial word.

Documenting how linguistic input may influence infants' spatial categorization offers an ideal forum for examining the larger issue of the interaction between cognition and language during development. Early cross-linguistic differences in young children's acquisition of language-specific spatial semantics have led to a lively debate about the necessity of language in the development of the underlying spatial concepts (Bowerman, 1996; Bowerman & Choi, 2001; Choi & Bowerman, 1991; Gentner & Boroditsky, 2001; Landau & Jackendoff, 1993; Mandler, 1992, 1996). One possibility is that spatial language plays a significant role in the development of spatial categories (e.g., Bowerman, 1996; Choi & Bowerman, 1991). Experience with particular spatial words may help shape the underlying concepts expressed in children's early semantic spatial categories. A contrasting possibility is that infants' nonlinguistic spatial cognition is sufficient in the formation of the spatial categories. In such a scenario, the language-specific semantic categories for spatial relations merely serve to select among the

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spatial concepts that are already available to the child (e.g., Mandler, 1992). Thus, the crux of the debate centers on the degree to which language on the one hand, and infants' nonlinguistic abilities on the other, drives the formation of the spatial concepts expressed in language-specific semantic categories.

In support of the sufficiency of nonlinguistic cognitive abilities in the formation of spatial categories, preverbal infants form abstract spatial categories of spatial relations (Casasola, Cohen, & Chiarello, 2003; Quinn, Cummins, Kase, Martin, & Weisman, 1996), including those not encoded in their language (Hespos & Spelke, 2004; McDonough, Choi, & Mandler, 2003). This ability, nonetheless, does not extend to all spatial relations. At 14 and 18 months, for example, infants still struggle in forming an abstract categorical representation of support, that is, placing one object on another (Casasola, 2005a, 2005b; Casasola & Cohen, 2002). After being habituated to a series of events depicting a support relation, infants discriminate a familiar support relation from an unfamiliar relation (such as containment), although this ability is dependent on viewing the support relation between familiar objects. When unfamiliar objects depict both the support and the unfamiliar relation, infants do not look significantly longer at the unfamiliar than the support relation, thus failing to demonstrate that they can discriminate support from other relations in this case. This reliance on familiar objects has been documented in infants' categorization of other spatial relations as well (Quinn, Adams, Kennedy, Shettler, & Wasnik, 2003; Quinn et al., 1996) and appears to be the first step in learning to form abstract categorical representations of spatial relations. Ultimately, infants do overcome their reliance on familiar objects and learn to generalize a spatial relation to unfamiliar objects to form the abstract categorical representation of relations such as containment and above versus below (Casasola & Cohen, 2002; Quinn et al., 1996, 2003).

In sum, infant spatial cognition is sufficient in forming some, but not all, spatial categories. In cases where infants do not form particular spatial categories, spatial language has been shown to facilitate this ability. When presented with the familiar spatial word "on" during habituation, infants of 18 months overcame their reliance on familiar objects and formed an abstract categorical representation of support (Casasola, 2005a). They looked significantly longer at a novel relation (containment) relative to the familiar support relation even when novel objects depicted each relation. In contrast, infants who viewed the events in silence only discriminated between the familiar support relation and the novel containment relation with familiar, but not novel, objects. Infants who heard attention-getting phrases during habituation provided no evidence of discriminating the support relation, ruling out the possibility that the effect of the spatial language was due to simply adding linguistic phrases to the events. Together, the results indicate that spatial language can lead infants to behave in a more developmentally mature manner: they progress from a reliance on familiar objects to generalizing the relation to novel objects.

One caveat is that the facilitative effect of spatial language on infants' spatial categorization has been demonstrated only with familiar spatial language. When Casasola (2005a) presented one group of 18-month-old infants with a novel spatial word ("toke") during habituation, infants failed to discriminate between the familiar support relation and the novel containment relation. The results suggested that the facilitative effect of spatial language on spatial categorization is restricted to instances in which infants have had previous experience with a particular spatial term.

However, the novel word condition used by Casasola (2005a) was far from ideal in testing the effect of a novel word on infants' spatial categorization. Both the novel and the familiar spatial words were presented in a general verb frame or in isolation ("Look. It goes on (toke). See? Goes on (toke). Wow! On (Toke)."). Infants who heard the familiar spatial word could rely on their previous experience with "on" to direct their attention to the support relation. In contrast,

infants who heard the novel word had little linguistic context to infer the possible referent of the novel word. Not surprisingly then, infants in the novel word condition failed to form the spatial category of support. These infants instead only discriminated between the familiar and the novel objects in the events, similar to the infants who heard the general language phrases during habituation. A lingering question is whether infants of 18 months would interpret a novel word as referring to the spatial relation if given a richer syntactic context and whether they then might use this information to facilitate their categorization of the support relation.

By 18 months, infants have learned that different grammatical forms refer to different commonalities in their environment. For example, when hearing a novel count noun, 18-month-old infants map the novel word onto the objects in a scene, but when hearing a novel verb, they instead map the novel word onto the actions (Echols & Marti, 2004). In addition, 18-month-olds can use a novel count noun to group a set of unfamiliar objects into a category (Booth & Waxman, 2002), whereas 14-month-olds required that a common function be paired with the novel count noun in order to do so. Nevertheless, 14-month-old infants have learned that novel count nouns refer to commonalities in the types of objects and show some sensitivity that novel adjectives refer instead to the properties of objects (Booth & Waxman, 2003), a contrast to infants of 11 months for whom both a novel count noun and a novel adjective will direct their attention to a wide range of commonalities among objects (Waxman & Booth, 2003). Thus, as children acquire language, they learn which grammatical forms refer to which commonalities in their environment.

By age 2, young children have learned which syntactic frames can refer to spatial relations (Fisher, Klinger, & Song, in press; Landau & Stecker, 1990). Children who heard “It is a corp” interpreted the novel count noun as referring to a novel object but interpreted the same novel word presented as a preposition, “It is acorp the box” as referring to the spatial relation. Although analogous findings are lacking with younger children, a number of findings suggest that this knowledge may be developing by 18 months. In a habituation task, 14-month-old infants learned to map novel spatial words onto dynamic containment and support events when these words were presented in sentences, such as “She’s putting Big Bird teek the box” (Casasola & Wilbourn, 2004). When tested with words in isolation, 14-month-olds failed to map novel words onto other action events (Casasola & Cohen, 2000), suggesting that infants may benefit from the presentation of the novel words in a linguistic context.

The present experiment was designed to explore whether a novel spatial word, embedded in a specific syntactic context, will facilitate 18-month-old infants’ ability to form an abstract categorical representation of support, a spatial category that infants of this age have difficulty forming (Casasola, 2005a; Casasola & Cohen, 2002). To rule out the possibility that simply hearing any novel word in a richer syntactic frame would direct infants’ attention to the spatial relation (the only commonality present across events), infants were randomly assigned to hear the same novel word as either a count noun (e.g., “It is a toke”) or a spatial particle (e.g., “She puts it toke”). If infants are sufficiently sensitive to the syntactic context such that hearing a spatial particle draws attention to the commonality of the spatial relation across the habituation events, then only infants in the novel particle condition should attend to the spatial relation. However, if any novel word draws attention to the commonalities across the events, infants who hear the novel count noun also should attend to the spatial relation. As a baseline comparison, a group of infants viewed the habituation and test events in silence.

In all the three conditions, infants were habituated to four different support events in which an object (the figure) was placed in a support relation to a second object (the referent object). These four events differed with respect to the figure and referent object. They also differed in the type of support relations depicted. Half of the support relations depicted a support relation in which the figure rests on the referent object, such as a cup placed on a dish (i.e., loose-on

support), whereas the remaining support relations depicted a tight-fit relation between the figure and the referent objects, such as a Lego block placed on another Lego block (i.e., tight-fit support). Thus, there was perceptual variability both in the objects used to depict the support relations and in the type of support relation presented during habituation.

Following habituation, infants viewed four test events: an event from habituation, an event with familiar habituation objects in a novel containment spatial relation, an event with the novel objects in the familiar support relation, and an event with other novel objects in the novel containment relation. If infants look significantly longer at the unfamiliar than at the familiar relation, both when familiar and novel objects depict each relation, infants are argued to have formed the abstract categorical representation of support. If infants only discriminate between the familiar and the novel relation when the objects depicting the relations are familiar, they will have provided evidence of discriminating a change in the relation but no evidence of forming the abstract categorical representation of support. Finally, if infants attend only to the objects in the dynamic events, then they should look significantly longer only at the two test events with novel objects relative to those with familiar objects, regardless of the spatial relation between those objects. Thus, infants' looking times to the four test events would provide insight into how infants were attending to the spatial events. If a novel spatial word does facilitate infants' formation of the abstract categorical representation of support, then infants in the novel particle condition, but not those in the novel count noun or silent conditions, should form the abstract spatial category of support.

Because the study focused on infants' understanding of spatial syntax, we thought it would be relevant to obtain a measure of infants' acquisition of spatial language. Parents were asked to report on their infants' comprehension and production of spatial words. This parental report allowed us to document whether infants' ability to use a novel spatial particle to facilitate their spatial categorization might vary as a function of their acquisition of spatial language.

Method

Participants

The participants were 42 infants of 17 – 19 months (*M* = 17.48 months, *SD* = 0.94 months, range = 16.53 –19.87 months), 23 females and 19 males. All infants were learning only English and came predominantly from middle-class families. Thirty-eight infants were Caucasian, three infants were Asian, and one infant was reported as "other" for ethnicity. An additional 11 infants were excluded from the final sample for the following reasons: 3 (2 in the silent condition and 1 in the novel count noun condition) failed to meet the habituation criterion (described below); 6 became too fussy or inattentive to complete the testing session (1 in the silent condition, 3 in the novel count noun condition, 2 in the novel particle condition); 1 infant in the novel particle condition could not be included because the mother spoke during the testing session; and 1 infant in the novel count noun condition moved out of the camera's view. All infants were recruited at the time of their birth from a local hospital. Once infants were within the appropriate age range for the present study, parents were contacted via letter and then a follow-up phone call. All infants received a T-shirt, bib, or spill-proof cup.

Stimuli

The stimuli were dynamic events of one object, the figure, placed in a support relation to a second object, the referent object. Each event began with the figure to the left of the referent object. After 1 s, a hand reached in, lifted the figure, and placed it in a support (i.e., on) or containment (i.e., in) relation to the referent object, where it remained in its spatial relation to the referent object for an additional second. The final frame of each support event and selected containment events can be seen in Figure 1.

Six different object pairs were used to depict a support relation: (a) a small blue car placed on a larger red car, (b) a small colorful bowl placed on an inverted white dog bowl, (c) a green Duplo® block placed on a red Duplo® block, (d) a cylindrical Duplo® man with red horizontal stripes placed on a blue Duplo® block with yellow wheels, (e) a turtle with a hole in the center of its shell placed on a pole and on two other turtles, and (f) a green peg placed on a yellow block.

Similarly, five object pairs were used to depict a containment relation: (a) a stuffed animal placed in a wicker basket, (b) a red candle in the shape of a ginger man placed in a cookie cutter of the same shape, (c) the colorful cup placed in the upright dog bowl, (d) the green peg placed in a hole in the yellow block, and (e) the small blue car was placed in the overturned red car, which was hollow. These last three containment events used objects pairs that also depicted a support relation. Although the orientation of the dog bowl and red car was different in the containment than in the support event, these objects were chosen because their appearance changed minimally despite the change in orientation.

All events were filmed using a Sony digital video camera. They were imported into a G4 Macintosh computer using Final Cut Pro and then edited in Quicktime. Each event was 6 s in duration and was looped five times without pauses to create trials that were 30 s in duration.

The auditory stimuli for two novel word conditions were recorded phrases spoken by a female voice in infant-directed speech. For the habituation phase, infants in both word conditions heard five phrases, one for each of the five repetitions of the event within a trial. In the novel particle condition, infants heard: “Look! She put it toke … Wow! She put it toke … She puts it toke … Yea! She put it toke … See? She put it toke.” Infants in the novel noun condition heard: “Look! It is a toke … Wow! It is a toke … It is a toke … Yea! It is a toke … See? It is a toke.” The first word in each phrase (e.g., “Look,” “Wow,” “Yea,” and “See?”) was designed to attract infants’ attention to the event and was presented as the hand reached for the figure. The second half of each phrase (e.g., “She put it toke” or “It is a toke”) was presented once the figure was in its spatial relation to the referent object. As the only exception, the third phrase (e.g., “She puts it toke” or “It is a toke”) was presented as the hand placed the figure in its support relation to the referent object. The phrases for the novel count noun and novel particle were matched in the number of syllables and prosody so that any difference in results could not be attributed to differences in surface features. The spatial word was presented as a spatial particle (i.e., “She puts it toke”) so that it could appear in a sentence final position, ensuring that the novel word would be sufficiently salient to infants and that the phrases for the novel particle condition would be equivalent to the phrases used in the count noun condition (“It is a toke”).

In both word conditions, five attention-getting phrases were used for the test trials: “Look! Ooh… . Wow! See? … Watch! Oh… . Did you see? … Look! Wow.” The first word in each phrase (e.g., “Look!,” “Wow!,” “Watch!”) was presented as the hand reached for the figure, and the second half of each phrase was presented after the figure was in its spatial relation to the referent object. As the only exception, the third phrase (“Did you see?”) was presented as the hand placed the figure in its relation to the referent object.

Apparatus

The experiment was conducted in adjoining experimenter and testing rooms. The testing room contained a 20-inch color computer monitor that was placed on a table at infants’ eye level and was about 127 cm from where the infant was seated. A Panasonic camera under the monitor was linked to a VCR and monitor in the adjoining room. This monitor allowed the experimenter to observe the infant and record their looking times during each trial using the Habit X program (Cohen, Atkinson, & Chaput, 2004) and a Macintosh G5 computer.

Procedure

Infants were randomly assigned to the silent, novel particle, or novel count noun condition, resulting in eight females and seven males in the silent condition, seven females and six males in the novel particle condition, and eight females and six males in the novel noun condition. After providing informed consent, parents completed the Location and Places section of the *MacArthur-Bates Communicative Development Inventory (CDI): Words and Gestures* (Fenson et al., 1993). Infants and their parents were then taken to the testing room, and infants were seated on their parent's lap in front of the monitor. From the adjoining room, the experimenter began the testing session by initiating the Habit program. An attention getter (a green circle that chimed as it expanded and contracted) was presented prior to each trial to direct infants' attention to the monitor. Once infants attended to the monitor, the experimenter depressed one key on the computer keyboard to begin a trial. During habituation, infants viewed four different support events chosen at random from the six possible support events. Infants viewed these four support habituation events until their looking time across three consecutive trials decreased by 50% from their looking time during the first three habituation trials.

During the test phase, infants viewed four trials. In the familiar test trial, infants viewed one of the events from habituation chosen at random. This test trial was included as a baseline and comparison to infants' looking to the novel test trials. In another test trial, they viewed objects seen during habituation but in a containment relation rather than in a support relation. Infants viewed two test events with novel objects. In one event, the relation was the familiar support relation, and in the other, the relation was a novel (containment) relation. Although the specific habituation and test events varied across infants, infants in each condition were matched on the habituation and test events viewed so that any difference across conditions could not be attributed to the presentation of specific habituation or test events. Finally, to establish interobserver reliability, the looking times of a randomly chosen sample of 16 infants were coded off – line. The average correlation between online and off – line looking time was .996 (range = .984 – .999), indicating high interobserver reliability.

Results

Spatial Vocabulary

The first analysis compared parental reports of the number of spatial words comprehended and produced by infants on the Locations and Places section of the *MacArthur-Bates Communicative Development Inventory: Words and Gestures* (Fenson et al., 1993). There were no significant differences among infants in each condition in the number spatial words comprehended, $F < 1$, *ns*, or produced, $F(2, 41) = 1.09$, *ns* (see the first two rows of Table 1), indicating that infants in each condition did not differ significantly in their acquisition of spatial words. There also was no significant difference across conditions in the number of infants reported to comprehend "on," $\chi^2(2, N = 42) < 1$, *ns*, although there was a significant difference in the number of infants who produced "on," $\chi^2(2, N = 42) = 7.32$, $p = .03$, because none of the infants in the silent condition were reported to produce "on."

Preliminary analyses failed to yield any significant differences in infants' looking times during the test trials as a function of their comprehension or production of "on." These two variables were consequently excluded from the analyses. An examination of infants' comprehension of the spatial words revealed that 21% of the infants in the sample comprehended all of the spatial words listed and that 76% of the sample comprehended 7 or more of the 11 spatial words, leaving little variation among infants in the number of spatial words comprehended. There was greater variation in the number of spatial words produced, with 38% of the sample not producing any spatial words, 33% producing one to three spatial words, and 29% producing five or more spatial words (none of the infants were reported to produce four spatial words).

Of interest for the present investigation was whether infants who produced spatial words, even one to three, might be sufficiently sensitive to the syntactic contexts of spatial words than infants not yet producing any spatial words. For this reason, infants were divided into two groups, those who produced spatial language and those who did not. Across conditions, there were no significant differences in the number of infants who did not yet produce spatial language (one female and three males in the novel particle condition, one female and four males in the novel count noun condition, and three females and four males in the silent condition), $\chi^2 < 1$, *ns*. This variable was taken into consideration when examining infants' looking times during habituation and test. Waxman and Markow (1995) had found differences in the abilities of high- versus low-vocabulary 12- and 13-month-old infants to use a novel word to facilitate their categorization of objects. These findings raised the possibility that infants' performance could differ significantly as a function of their acquisition of spatial words, with infants producing spatial words more likely to use the novel spatial particle to facilitate their spatial categorization relative to infant not yet producing any spatial words.

Habituation Phase

Infants' looking time during habituation was compared to their looking time to the familiar test event, which presented one of the events seen during habituation. This analysis was included to rule out the possibility that infants met the habituation criterion as an artifact. Infant sex was not included as a variable because preliminary analyses failed to reveal any significant differences in the habituation task due to infant sex. Rather, infants' production of spatial language on the CDI (none vs. some spatial words produced) was included as a variable. Infants' looking times were analyzed in a 3 (condition: silent vs. novel particle vs. novel count noun) × 2 (spatial language produced: none vs. some) × 2 (trials: average of the first three habituation trials vs. the familiar test trial) mixed-model analysis of variance (ANOVA). The analysis yielded a significant effect of trials, $F(1, 36) = 172.52$, $p < .001$, $\eta_p^2 = .83$. Infants looked significantly longer at the habituation events during the first three trials of habituation (M = 26.34 s, SD = 4.43 s) than at one of the habituation events presented as the familiar test event (M = 9.88 s, SD = 7.28 s). The analysis did not yield any other significant effects.

Test Phase

The next analysis explored the central question of the study. Did infants form an abstract categorical representation of support and did this ability differ across conditions? The lower half of Table 1 lists infants' looking times to the four test events in each condition. If infants formed the abstract categorical representation of support, they were expected to look significantly longer at the novel containment relation than at the familiar spatial relation, both when the objects depicting the relations were familiar and when they were novel.

Infants' looking times during the test were examined in a 2 (condition) × 2 (spatial language produced) × 2 (objects: familiar vs. novel) × 2 (spatial relation: familiar vs. novel) mixed-model ANOVA. The analysis yielded a significant effect of objects, $F(1, 36) = 16.87$, $p < .001$, $\eta_p^2 = .32$. Infants looked significantly longer at the two test trials with novel objects (M = 16.14 s, SD = 7.59 s) than at the two test trials with familiar objects (M = 11.35 s, SD = 6.58 s). The analysis also yielded a significant effect of spatial relation, $F(1, 36) = 9.42$, $p = .004$, $\eta_p^2 = .21$. Infants looked significantly longer at the two test trials with the novel containment relation (M = 15.22 s, SD = 8.27 s) than at the two test trials with the familiar support relation (M = 12.27 s, SD = 6.09 s).

These main effects, however, were qualified by a significant Condition × Spatial Language Produced × Spatial Relation interaction, $F(2, 36) = 5.21$, $p = .01$, $\eta_p^2 = .23$, indicating that infants' looking time to the familiar versus novel spatial relation differed significantly across conditions

and whether infants were reported by their parents to produce spatial words. To explore the source of this interaction, infants' looking time to the test trials was analyzed separately by condition.

For infants in the silent condition, a 2 (spatial language produced) ×2 (objects) ×2 (spatial relation) ANOVA yielded only a significant effect of objects, $F(1, 13) = 6.22$, $p = .03$, $\eta_p^2 = .32$. Infants looked significantly longer at the novel ($M = 16.01$ s, $SD = 6.75$ s) than familiar objects ($M = 10.83$ s, $SD = 6.39$ s). There was no significant effect of spatial relation, $F < 1$, *ns*. There was, however, a marginal interaction of spatial relation and spatial language produced, $F(1, 13) = 3.59$, $p = .08$, $\eta_p^2 = .22$. As can be seen in Figure 2, the eight infants who were producing spatial language tended to look longer at the two test trials that presented the novel relation ($M = 16.89$ s, $SD = 8.28$ s) than the two test trials that presented the familiar spatial relation ($M = 11.52$ s, $SD = 3.66$ s), $F(1, 7) = 2.77$, $p = .14$, whereas the seven infants not producing any spatial language did not ($M = 11.11$ s, $SD = 8.31$ s for the novel relation and $M = 13.94$ s, $SD = 6.32$ s for the familiar spatial relation), $F(1, 6) = 1.03$, *ns*. There also was a marginally significant interaction of spatial relation and objects, $F(1, 13) = 3.39$, $p = .09$, $\eta_p^2 = .21$. Infants looked significantly longer at the novel than familiar spatial relation when the objects were familiar, $F(1, 13) = 8.20$, $p = .01$, $\eta_p^2 = .39$, but not when they were novel, $F < 1$, *ns*. That is, infants in the silent condition, particularly those reported to be producing spatial words, discriminated the change in spatial relation but did not generalize the support relation to novel objects to form the abstract categorical representation of support.

For infants in the novel particle condition, a 2 (spatial language produced) × 2 (objects) × 2 (spatial relation) ANOVA yielded a marginal effect of objects, $F(1, 11) = 4.28$, $p = .06$, $\eta_p^2 = .28$, with infants looking somewhat longer at the novel ($M = 16.53$ s, $SD = 8.78$ s) than familiar objects ($M = 11.70$ s, $SD = 7.86$ s). There was a significant effect of spatial relation, $F(1, 11) = 17.15$, $p = .003$, $\eta_p^2 = .61$, with infants looking significantly longer at the two test trials presenting the novel relation ($M = 16.63$ s, $SD = 8.49$ s) than at the two test trials that presented the familiar spatial relation ($M = 11.60$ s, $SD = 7.09$ s). The analysis did not yield any other significant effects. As can be seen in Figure 3, infants in the novel particle condition looked longer at the novel than familiar relation, regardless of object familiarity or novelty. Most importantly, they looked significantly longer at the novel than familiar relation when the objects were novel, $F(1, 11) = 10.43$, $p = .008$, $\eta_p^2 = .49$. There was no significant interaction of spatial language produced for this comparison, $F(1, 11) = 1.28$, $p = .28$. Thus, infants in the novel word condition provided evidence of forming an abstract categorical representation of support, and this ability did not differ as a function of their production of spatial words on the CDI.

For infants in the novel count noun condition, a 2 (spatial language produced) × 2 (objects) × 2 (spatial relation) ANOVA yielded a significant effect of objects, $F(1, 12) = 7.30$, $p = .02$, $\eta_p^2 = .38$. Infants looked significantly longer at the novel ($M = 15.90$ s, $SD = 7.81$ s) than familiar objects ($M = 11.60$ s, $SD = 5.92$ s). The analysis also yielded a significant interaction of spatial language produced and spatial relation, $F(1, 12) = 4.75$, $p = .05$, $\eta_p^2 = .28$ (see Figure 4). The five infants not yet producing any spatial language looked longer at the two test trials that presented the novel containment relation ($M = 17.76$ s, $SD = 5.20$ s) than at the two test trials that presented the familiar support relation ($M = 9.64$ s, $SD = 4.31$ s), $F(1, 4) = 5.20$, $p < .09$, $\eta_p^2 = .57$, whereas the nine infants who were producing spatial words did not (novel relation: $M = 13.48$ s, $SD = 9.44$ s; familiar relation: $M = 14.07$ s, $SD = 7.22$ s), $F < 1$, *ns*. Thus, infants who were not yet producing spatial words provided some evidence of discriminating the spatial relation, whereas those who did produce spatial words did not.

A final analysis compared the 9 infants in the novel count noun condition who were producing spatial words to the 13 infants in the novel particle condition in a 2 (word condition: count noun vs. particle) × 2 (objects) × 2 (spatial relation) ANOVA. The analysis yielded a significant Spatial Relation × Condition interaction, $F(1, 20) = 5.98$, $p = .02$, $\eta_p^2 = .23$. Infants in the novel count noun condition who were producing spatial words demonstrated a significantly different pattern of results than infants in the novel particle condition. In contrast, the five infants in the novel count noun condition who were not yet producing any spatial language did not differ significantly from the infants in the novel particle condition in their discrimination of the familiar versus novel spatial relation, $F(1, 16) = 1.21$, *ns*.

Discussion

The present experiment was designed to explore the degree to which infants can use a novel particle to facilitate their categorization of a support relation in dynamic spatial events. The findings indicate that presenting a novel particle with each example of support during habituation aided 18-month-old infants in forming an abstract categorical representation of support, a spatial category not formed by infants who viewed the events in silence or by the majority of infants who were presented with a novel count noun rather than the novel particle. Infants who viewed the events in silence discriminated between the familiar and the novel spatial relation with familiar but not novel objects. That is, these infants did not form an abstract categorical representation of support. Similarly, the majority of infants in the novel count noun condition failed to discriminate between the familiar support relation and the novel containment relation across both familiar and novel objects. This general pattern of results suggests that 18-month-old infants are sufficiently familiar with the syntactic context of a novel spatial particle and provides the first evidence that 18-month-old infants can use a novel spatial particle to facilitate their formation of an abstract spatial category.

However, when infants' productive spatial vocabulary was taken into consideration, a more complex interaction between spatial language and infants' spatial categorization emerged. First, there was a hint in the results that infants' production of spatial language influenced their attention to the support relation in the silent condition. Infants who were producing spatial words looked significantly longer at the novel than familiar relation when familiar objects depicted each relation, providing evidence of successfully discriminating the support and containment relations. In contrast, infants who were not yet producing spatial language did not. The results suggest that infants who have acquired spatial words in their expressive vocabularies may be more sensitive to a support relation than infants who have yet to achieve this linguistic milestone. Nonetheless, even infants with a productive spatial vocabulary did not generalize the support relation to novel objects when viewing these events in silence, failing to demonstrate that they could form the abstract categorical representation of support without the assistance of a novel word.

Second, there was a clear effect of infants' production of spatial language on their looking time to the test events in the novel count noun condition. For infants reported to be producing spatial words, the novel count noun did not direct their attention to the support relation. These infants failed to look significantly longer at the novel containment than familiar support relation, even when familiar objects depicted each relation. If the results from only these infants are compared to infants in the novel particle and silent conditions, then a novel spatial particle appears to uniquely direct attention to the spatial relation and facilitates infants' ability to form the abstract categorical representation. However, when the results of the five infants in the novel count condition who were not yet producing spatial vocabulary are considered, the results instead suggest that a novel count noun, similar to a novel spatial particle, will direct infants' attention to a support relation. The infants lacking a productive spatial vocabulary yielded a marginal effect of spatial relation, providing some evidence that they were discriminating between the

familiar support and the novel containment relations despite hearing the novel word as a count noun. In fact, a comparison of the results for infants in the particle condition in Figure 3 and infants in the count noun condition with no spatial vocabulary in Figure 4 shows a strikingly similar pattern of results as well as comparable effect sizes (η_p^2=.61 and η_p^2=.57, respectively).

Why would infants lacking a productive spatial vocabulary attend to the spatial relation when hearing a novel count noun? Infants not yet producing any spatial words may be sufficiently familiar with grammatical forms to know that a count noun refers to a commonality in their environment but may not have learned yet to narrow this expectation to categories of objects. This suggestion of a developmental progression in infants' sensitivity to varying grammatical forms is similar to arguments and findings by Waxman and Booth. By 13 months, infants have begun to learn that novel count nouns refer specifically to object categories and novel adjectives to their properties, although at 11 months, both a novel count noun and a novel adjective will direct infants' attention to a wide range of commonalities among objects (Booth & Waxman, 2003; Waxman, 1999; Waxman & Booth, 2001, 2003). The current study extends these findings to infants' understanding of the relation between spatial categories and spatial particles while at the same time suggesting that this understanding may be more closely intertwined with infants' own linguistic experience than has been previously demonstrated. Furthermore, the current findings suggest that infants' understanding of spatial particles may emerge at a later point in development than their understanding of nouns and adjectives. For infants of 18 months who lack a productive spatial vocabulary, a novel count noun directed attention to commonalities in a spatial relation, demonstrating that for these 18-month-old infants, novel count nouns were tied to commonalities in their environment that extended beyond the objects and their properties. That is, the results suggest that novel count nouns will direct attention to whatever commonalities are present, even when these commonalities are not linked to objects. In contrast, infants producing spatial words (who were the majority of infants in the sample) have learned that novel spatial particles but not novel count nouns refer to spatial relations. A novel count noun failed to direct attention to the spatial relation for these more linguistically advanced infants.

The results suggest a developmental progression in which any novel word embedded in a syntactic frame will direct infants to attend to commonalities in the spatial relation across dynamic events. As infants acquire a productive spatial vocabulary, they learn that novel spatial particles specifically refer to the spatial relations in a dynamic event and they narrow their expectations for how novel words, in a syntactic frame, refer to commonalities across events (akin to how they learn to narrow their interpretations of novel count nouns and novel adjectives, e.g., Waxman, 1999). Because only spatial vocabulary was measured in the present experiment, it is uncertain whether the differences across the two groups of infants are due specifically to their production of spatial words or to a more general limitation of vocabulary development. Infants who are not yet producing spatial words may have a limited acquisition of count nouns and for this reason may interpret count nouns as referring to the support spatial relation. Alternatively, perhaps it is only after infants have begun to produce spatial words that they develop their sensitivity to the different syntactic contexts that may signal a spatial relation. It may be that these infants will disambiguate between novel count nouns and novel adjectives but will not learn to refine their interpretation of novel count nouns as not referring to a spatial relation until they have begun to produce spatial words.

These arguments, however, cannot account for the findings reported by Casasola (2005a) in which 18-month-old infants who heard a novel word did not attend to the spatial relation. This previous study used the same novel word and spatial events as the present study, and yet, infants in this previous study only discriminated between the familiar and the novel objects. In addition, their discrimination of the spatial relation did not vary as a function of their production or comprehension of spatial words, including the spatial word "on." The difference in results

may lie in the richness of the syntactic frame. Possibly, when a novel word is presented in a richer syntactic frame, infants are provided with sufficient information to be cued to attend to a commonality in the events. For infants lacking a productive spatial vocabulary, the syntactic frame directs attention to whatever commonality is present, whereas for infants with a productive spatial vocabulary, this effect is specific to a novel particle and the spatial relation. In contrast, when the syntactic frame is minimal and, thus, not sufficiently specific, the novel word may be too ambiguous to reliably draw infants' attention to any commonality in the event, including the spatial relation. Recall that the 18-month-old infants in the Casasola (2005a) study heard the novel word in a general verb frame (i.e., "It goes toke") and at times, in isolation. Without a clear reference to any element in the events, the presence of this novel word added an additional processing load and resulted in infants only discriminating the most salient aspect of the events, the objects. Infants in the general language condition similarly only discriminated the change in objects consistent with the argument that when the linguistic input lacks a clear reference, infants do not attend to the relational commonality of the support relation in the events.

The difference in results across the two studies suggests that infants of 18 months use the syntactic frame of a novel word to infer that the word refers to the spatial relation *provided that infants are producing spatial words*. The difference between the present results and those reported by Casasola (2005a) also suggests that infants depend on a richer syntactic frame for novel but not familiar spatial words, presumably because the familiarity of the familiar spatial words may be sufficient in directing infants to the relevant spatial relation. However, additional research is needed to pinpoint the degree to which infants of 18 months rely exclusively on the syntactic frame versus other information in the input to facilitate their categorization of the support relation. Possibly, infants in the novel particle condition benefited from, or even depended on, the familiar verb "put" to facilitate their spatial categorization. Additional studies are needed to test whether the same results would emerge if a different verb, such as "place," or a more general verb and a preposition are presented to infants (e.g., "it is X the box"). An intriguing possibility is that infants do initially depend on particular verbs and specific syntactic constructions to facilitate their spatial categorization, but once their spatial vocabularies develop further, they demonstrate less reliance on specific or highly familiar verbs (such as "put") and learn to use a variety of spatial syntactic constructions to facilitate their spatial categorization. Although the present results offer the first evidence that infants use the syntactic frame of a novel particle to facilitate their spatial categorization, future studies must address whether infants rely solely on this syntactic information or whether they recruit assistance from familiar verbs as well.

Findings from the five infants in the noun condition suggest that simply providing a richer syntactic context for the novel word was sufficient in aiding low-vocabulary infants' spatial categorization. Hence, for infants without a productive spatial vocabulary, manipulations in the familiarity of the verb and the specific syntactic frame may not matter. But for this group of infants as well, additional research is needed to understand why they did not discriminate a change in the support relation when viewing the events in silence but then attended to the relation when hearing a novel count noun. Given the findings that infants of 13 months can distinguish between count nouns and adjectives (Waxman, 1999), it is surprising that infants of 18 months would attend to a spatial relation when hearing a novel count noun. The results from the infants producing spatial words are much easier to understand across the three conditions: When viewing the events in silence, infants who produce spatial words are sensitive to a support relation (they discriminate it from an unfamiliar relation), and when hearing a novel spatial particle, but not when hearing a novel count noun, they form the abstract spatial category. Testing younger infants in the same task may provide insight into whether the pattern of the no-spatial vocabulary 18-month-old infants reflects a developmental stage that precedes

the pattern demonstrated by the 18-month-old infants who were producing spatial words or whether this pattern of results is specific to infants with low vocabularies.

How do these results inform the debate about the role of infant nonlinguistic spatial cognition versus language in the formation of infants' spatial categories? The results show that a novel spatial particle (and for a few infants, a novel count noun) aided infants in forming a spatial category that they otherwise would not have formed. Infants of 14 months can learn to form a spatial category of support without the aid of spatial language, but only do so if viewing one type of support relation (loose-on, such as a cup placed on an inverted bowl) and two exemplars during habituation (Casasola, 2005b). The importance of spatial language in forming a category of support arises when infants are habituated to additional examples of support as well as a variety of support relations (e.g., loose-on and tight-fit). The perceptual similarity among these events appears to be insufficient for infants to note and abstract the support relation when viewing these events in silence (Casasola & Cohen, 2002). Providing a novel spatial particle (and for a few infants, even a novel count noun) appears to direct infants' attention to the common support relation across the different types of support relations presented during habituation, thereby facilitating their ability to form the abstract categorical representation of support. That is, a novel word aided infants in forming a broader and more diverse category of support that they would otherwise form. Nonetheless, an important caveat is that the necessity of spatial language in forming spatial categories appears to vary with the heterogeneity of the spatial category (Casasola, Bhagwat, & Ferguson, 2006; Casasola, in press). For homogenous spatial categories, such as containment, infants easily form the spatial category without any need for spatial language to facilitate their spatial categorization. Rather, the importance of spatial language appears to arise for these more diverse spatial categories, such as support.

The present results begin to offer some insight into how infants may learn to form language-specific semantic categories. As their linguistic abilities develop, infants learn about the syntactic contexts specific to their language that refer to the relations between objects, and they can begin to recruit this knowledge in forming particular semantic categories. For those spatial categories that are challenging for infants to form, the presence of a novel spatial particle functions to direct their attention specifically to the spatial relation. This increased attention can facilitate their ability to form an abstract categorical representation of the spatial relation by directing their attention to the relevant commonalities of the spatial relation across events. In this manner, infants' own linguistic abilities begin to contribute both to the acquisition of underlying spatial categories and to their acquisition of language-specific semantic categories. That is, infants' own cognitive and linguistic abilities modify the extent to which spatial language can and does influence infants' spatial categorization.

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References

Balaban MT, Waxman SR. Do words facilitate object categorization in 9 -month-old infants? Journal of Experimental Child Psychology 1997;64:3–26. [PubMed: 9126625]

Booth AE, Waxman SR. Object names and object functions serve as cues to categories for infants. Developmental Psychology 2002;38:948–957. [PubMed: 12428706]

Booth AE, Waxman SR. Mapping words to the world in infancy: Infants' expectations for count nouns and adjectives. Journal of Cognition and Development 2003;4:357–381.

Bowerman, M. Learning how to structure space for language: A cross-linguistic perspective. In: Bloom, P.; Peterson, MA.; Nadel, L.; Garrett, MF., editors. Language and space. Cambridge, MA: MIT Press; 1996. p. 385-436.

Bowerman, M.; Choi, S. Shaping meanings for language: Universal and language-specific in the acquisition of spatial semantic categories. In: Bowerman, M.; Levinson, S., editors. Language acquisition and conceptual development. Cambridge, UK: Cambridge University Press; 2001. p. 475-511.

Casasola M. Can language do the driving? The effect of linguistic input on infants' categorization of support spatial relations. Developmental Psychology 2005a;41:183–192. [PubMed: 15656748]

Casasola M. When less is more: How infants learn to form an abstract categorical representation of support. Child Development 2005b;76:279–290. [PubMed: 15693772]

Casasola M. The development of infants' spatial concepts. Current Directions in Psychological Science. in press

Casasola, M.; Bhagwat, J.; Ferguson, K. Precursors to verb learning: Infants' understanding of motion events. In: Hirsh-Pasek, K.; Golinkoff, RM., editors. Action meets word: How children learn verbs. Oxford, UK: Oxford University Press; 2006. p. 160-190.

Casasola M, Cohen LB. Infants' association of language labels with causal actions. Developmental Psychology 2000;36:155–168. [PubMed: 10749073]

Casasola M, Cohen LB. Infant categorization of containment, support, and tight-fit spatial relationships. Developmental Science 2002;5:247–264.

Casasola M, Cohen LB, Chiarello E. Six-month-old infants' categorization of containment spatial relations. Child Development 2003;74:679–693. [PubMed: 12795384]

Casasola M, Wilbourn MP. Fourteen-month-old infants form novel word-spatial relation associations. Infancy 2004;6:385–396.

Choi S, Bowerman M. Learning to express motion events in English and Korean: The influence of language-specific lexicalization patterns. Cognition 1991;41:83–121. [PubMed: 1790656]

Cohen, LB.; Atkinson, DJ.; Chaput, HH. Habit X: A new program for obtaining and organizing data in infant perception and cognition studies (Version 1.0). Austin: University of Texas; 2004.

Echols, CH.; Marti, CN. The identification of words and their meanings: From perceptual biases to language-specific cues. In: Hall, DG.; Waxman, SR., editors. Weaving a lexicon. Cambridge, MA: MIT Press; 2004. p. 41-78.

Fenson, L.; Dale, PS.; Reznick, JS.; Thal, D.; Bates, E.; Pathick, S., et al. MacArthur-Bates Communicative Development Inventories: Words and gestures. Baltimore: Paul H. Brookes Publishing; 1993.

Fisher C, Klingler SL, Song H. What does syntax say about space? 2-year-olds use sentence structure to learn new prepositions. Cognition 2006;101:B19–B29. [PubMed: 16364280]

Gentner, D.; Boroditsky, L. Individuation, relativity and early word-learning. In: Bowerman, M.; Levinson, SC., editors. Language acquisition and conceptual development. Cambridge, UK: Cambridge University Press; 2001. p. 215-256.

Gopnik A, Choi S. Do linguistic differences lead to cognitive differences? A cross-linguistic study of semantic and cognitive development. First Language 1990;10:199.

Gopnik A, Choi S, Baumberger T. Cross-linguistic differences in early semantic and cognitive development. Cognitive Development 1996;11:197–227.

Gopnik A, Meltzoff A. Relations between semantic and cognitive development in the one-word stage: The specificity hypothesis. Child Development 1986;57:1040–1053.

Gopnik A, Meltzoff A. The development of categorization in the second year and its relation to other cognitive and linguistic developments. Child Development 1987;58:1523–1531.

Gopnik A, Meltzoff A. Categorization and naming: Basic-level sorting in eighteen-month-olds and its relation to language. Child Development 1992;63:1091–1103.

Hespos SJ, Spelke ES. Conceptual precursors to language. Nature 2004;430:453–456. [PubMed: 15269769]

Landau B, Jackendoff R. What" and "where" in spatial language and spatial cognition. Behavioral and Brain Sciences 1993;16:217–265.

Landau B, Stecker DS. Objects and places: Geometric and syntactic representations in early lexical learning. Cognitive Development 1990;5:287–312.

Mandler JM. How to build a baby. II: Conceptual primitives. Psychological Review 1992;99:587–604. [PubMed: 1454900]

Mandler, JM. Pre-verbal representation and language. In: Bloom, P.; Peterson, MA.; Nadel, L.; Garrett, MF., editors. Language and space. Cambridge, MA: MIT Press; 1996. p. 365-384.

McDonough L, Choi S, Mandler JM. Understanding spatial relations: Flexible infants, lexical adults. Cognitive Psychology 2003;46:229–259. [PubMed: 12694694]

Piaget, J.; Inhelder, B. The child's conception of space. New York: W.W. Norton; 1967.

Quinn PC, Adams A, Kennedy E, Shettler L, Wasnik A. Development of an abstract category representation for the spatial relation between in 6- to 10-month-old infants. Developmental Psychology 2003;39:151–163. [PubMed: 12518816]

Quinn PC, Cummins M, Kase J, Martin E, Weisman S. Development of categorical representations for above and below spatial relations in 3- to 7-month-old infants. Developmental Psychology 1996;32:942–950.

Vygotsky, LS. Thought and language. Cambridge, MA: MIT Press; 1962.

Waxman SR. Specifying the scope of 13-month-olds' expectations for novel words. Cognition 1999;70:B35–B50. [PubMed: 10384739]

Waxman SR, Booth AE. Seeing pink elephants: Fourteen-month-olds' interpretations of novel nouns and adjectives. Cognitive Psychology 2001;43:217–242. [PubMed: 11689022]

Waxman SR, Booth AE. The origins and evolution of links between word learning and conceptual organization: New evidence from 11-month-olds. Developmental Science 2003;6:128–135.

Waxman SR, Markow DB. Words as invitations to form categories: Evidence from 12- to 13-month-old infants. Cognitive Psychology 1995;29:257–302. [PubMed: 8556847]

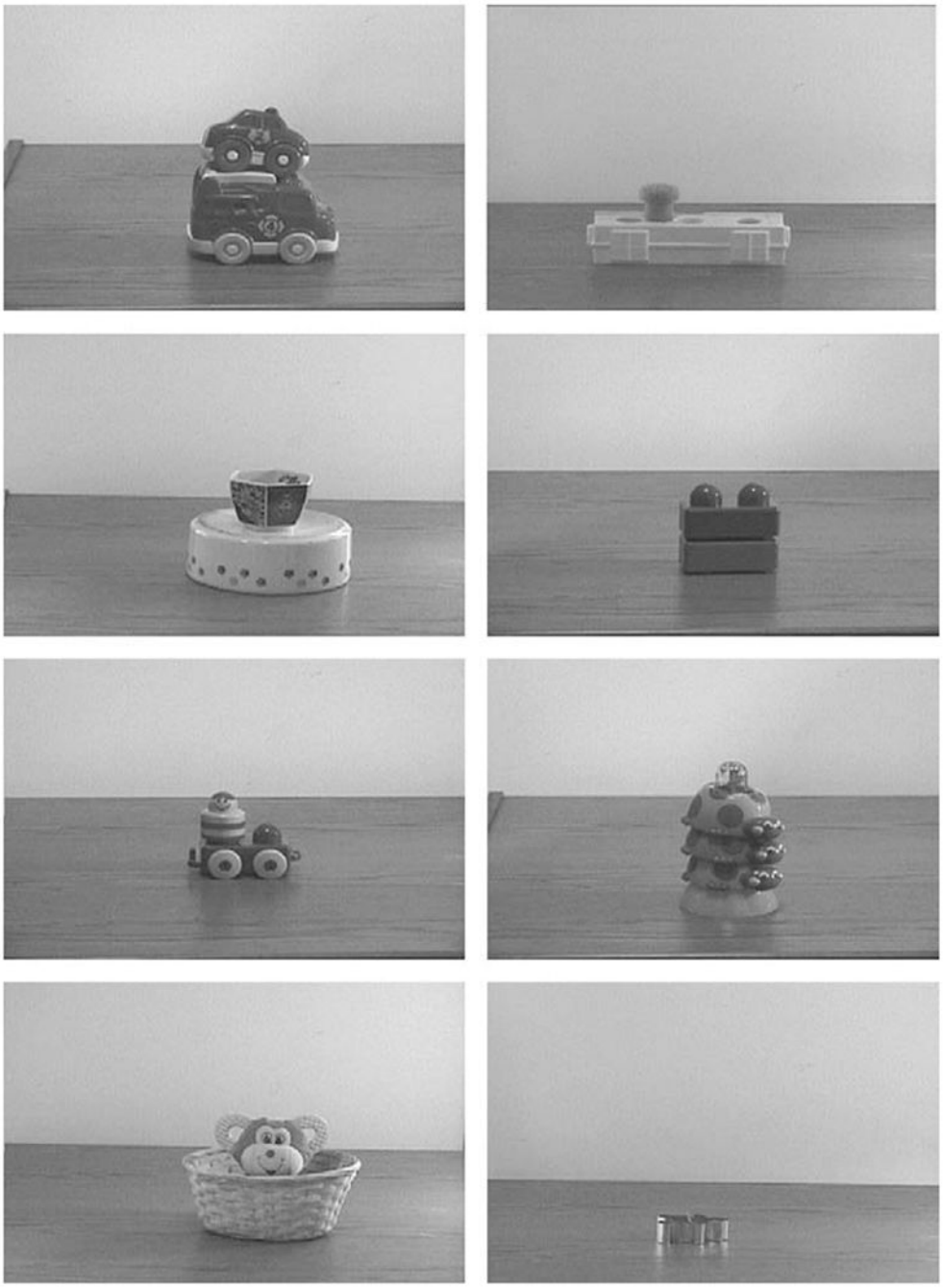

Figure 1.
The final frame of all six support events (top three rows) and an example of two containment events (bottom row).

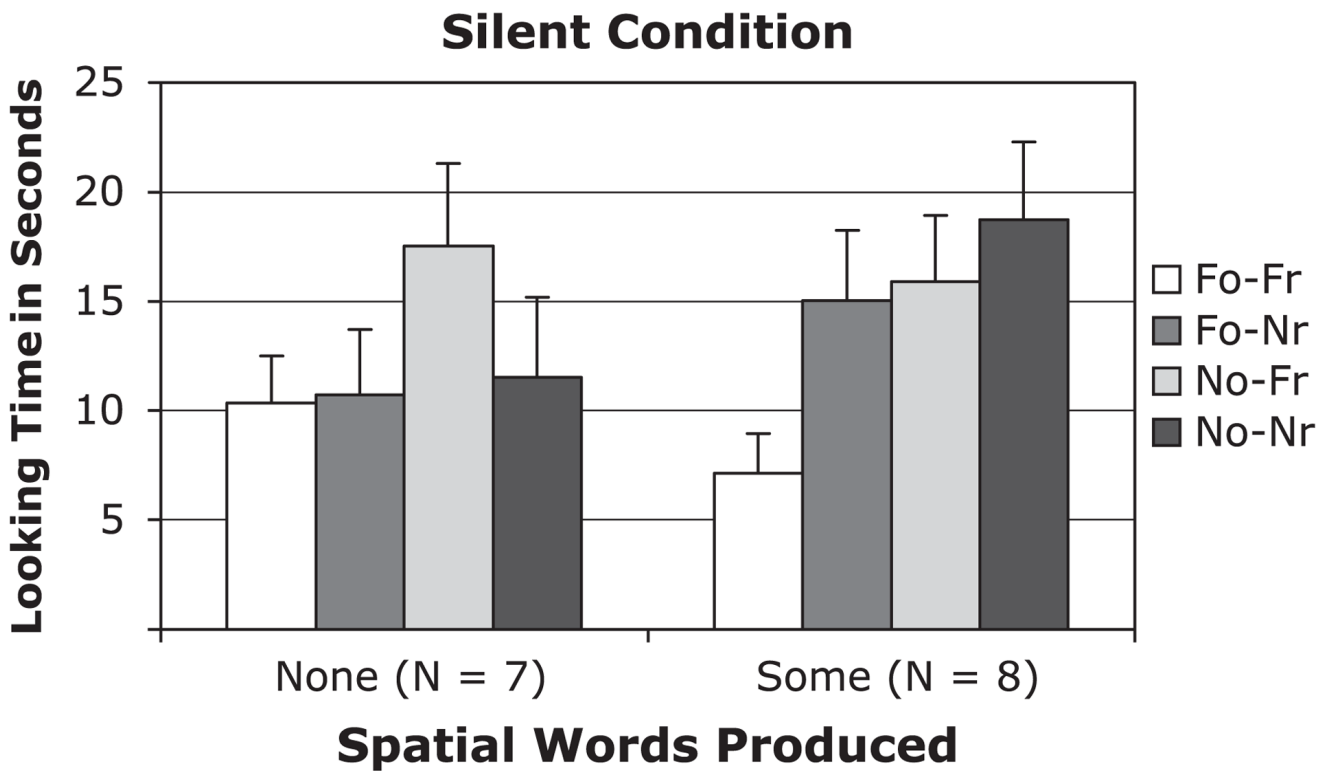

Figure 2.
For infants in the silent condition, their looking times to the familiar versus novel spatial relation when the objects were familiar and when the objects were novel as a function of whether they were producing some or no spatial words.

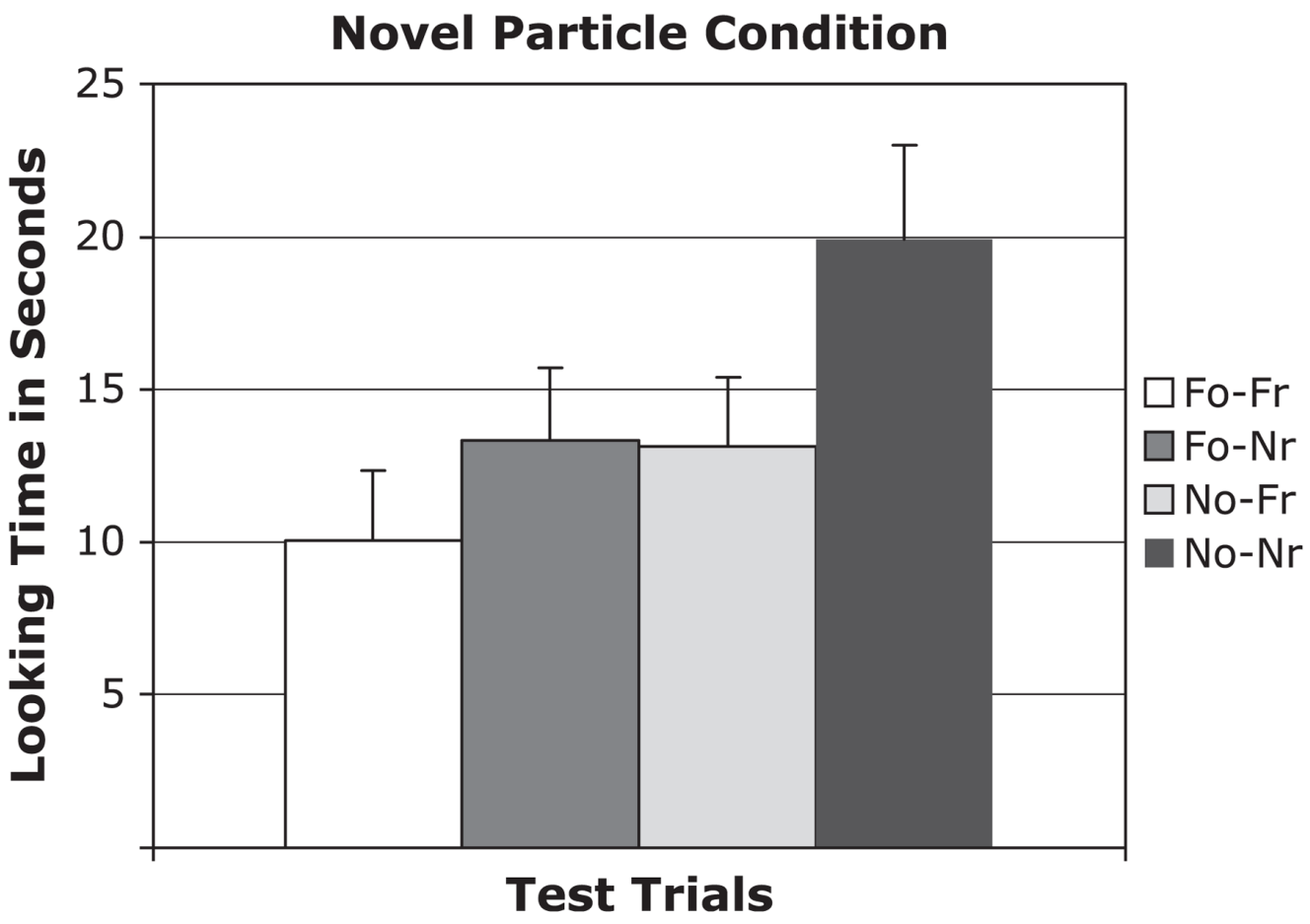

Figure 3.
For infants in the novel particle condition, their looking times to the familiar versus novel spatial relation when the objects were familiar and when the objects were novel.

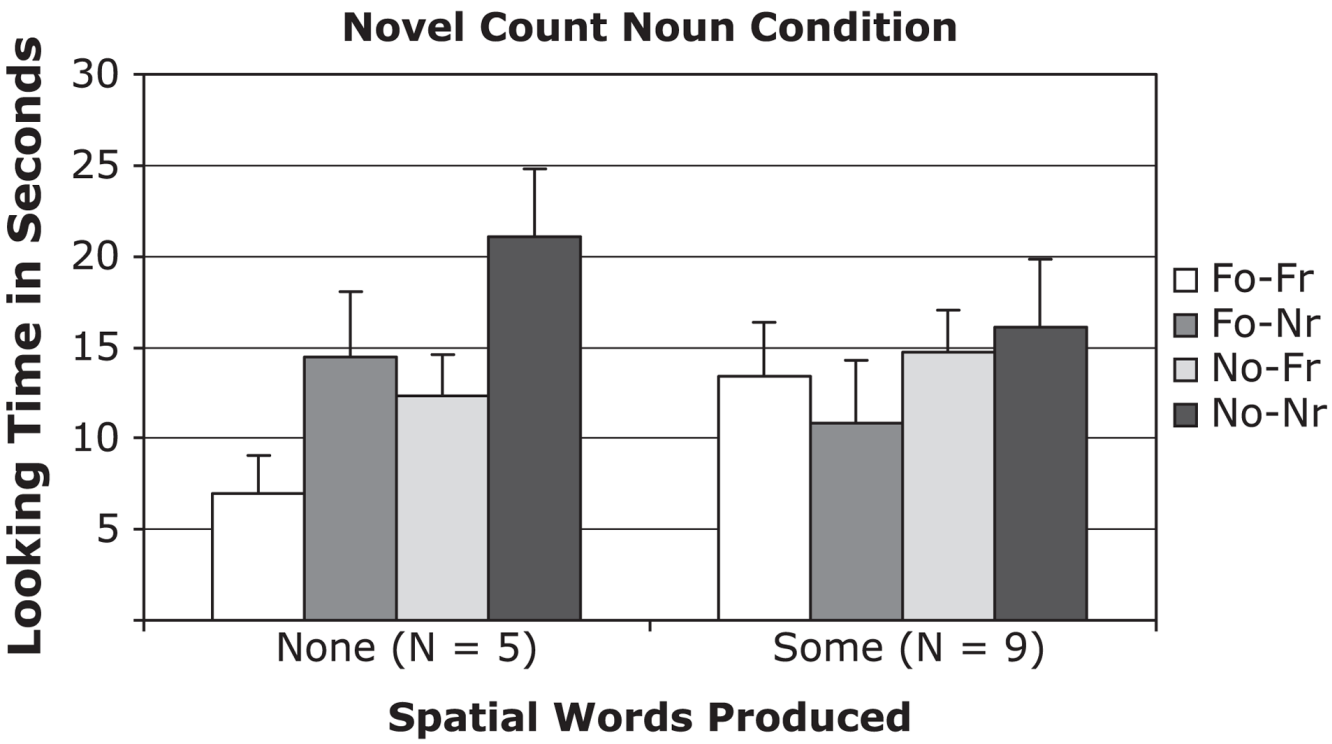

Figure 4.
For infants in the novel count noun condition, their looking time to the familiar versus novel spatial relation when the objects were familiar and when the objects were novel as a function of whether infants were reported to produce spatial words.

Table 1

For Infants in Each Condition, the Mean (Standard Deviation) of the Vocabulary Measures on the CDI and for Looking Time to Each Test Trial

	Silent	Novel count noun	Novel particle
No. of spatial words comprehended	7.13 (3.72)	7.86 (2.96)	7.85 (3.67)
No. of spatial words produced	1.53 (2.30)	2.86 (2.60)	2.77 (3.19)
Mean of first three habituation trials (s)	26.53 (4.55)	26.06 (5.22)	26.42 (3.64)
Familiar objects in the familiar relation (s)	8.63 (5.52)	11.07 (8.27)	10.05 (8.23)
Familiar objects in a novel relation (s)	13.03 (8.56)	12.12 (9.41)	13.35 (8.57)
Novel objects in a familiar relation (s)	16.67 (8.95)	13.91 (8.68)	13.15 (8.14)
Novel objects in a novel relation (s)	15.36 (10.29)	17.90 (10.20)	19.92 (11.01)