Cognition 164 (2017) 174–187

Contents lists available at ScienceDirect

Cognition

journal homepage: www.elsevier.com/locate/COGNIT

Original Articles

The relationship between pre-verbal event representations and semantic structures: The case of goal and source paths

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ARTICLE INFO

Article history:
Received 2 October 2014
Revised 28 March 2017
Accepted 6 April 2017

Keywords:
Goal path
Source path
Motion event
Semantic representation
Infant cognition
Categorization
Language development

ABSTRACT

We explored the nature of infants' concepts for goal path and source path in motion events (e.g., the duck moved into the bowl/out of the bowl), specifically asking how infants' representations could support the acquisition of the semantic roles of goal path and source path in language. The results showed that 14.5-month-old infants categorized goal paths across different motion events (moving *to X*, moving *on Y*), and they also categorized source paths if the source reference objects were highly salient (relatively large in size and colorful). Infants at 10 months also categorized goal paths, suggesting that the broad concept GOAL PATH precedes the acquisition of the relevant spatial terms (e.g., "to", "onto"). These results are discussed in terms of the nature of goal and source path representations in infancy (e.g., whether they are represented at a general level – one that encompasses specific relations such as containment and support) as well as the possible mechanisms that may be involved in the mapping of these representations to language.

1. Introduction

Consider the event of a girl skipping out of school and into a sandbox. Infants perceive such events and young children readily talk about them. How is this accomplished? Children must first parse the event into its relevant components (e.g., girl, skip, out, school, into, sandbox). Then, they must categorize the objects, actions, and spatial relations such that they can be mapped into a linguistic structure (for example, in English, girl = object → noun phrase, skip = action → verb phrase, out of school = from path + reference object → prepositional phrase, into a sandbox = to path + reference object → prepositional phrase). Given the coarseness and abstractness of linguistic representations (Jackendoff, 1983; Landau & Jackendoff, 1993), the following question arises: what is the nature of event representations in the pre-verbal infant, such that these representations can support language development?

Theories in language acquisition offer at least two viable alternatives, each of which has received support from empirical research. First, infants' event representations may map ('link') readily into language (e.g., Bloom, 1999; Landau & Gleitman, 1985; Pinker, 1984). In support of this, infants and young children map objects to nouns (Bloom, 1999; Grimshaw, 1981; Waxman & Booth, 2001), properties to adjectives (Waxman & Markow, 1998), actions to verbs (Golinkoff et al., 2002), and agents to subjects (Fisher, Hall, Rakowitz, & Gleitman, 1994). Alternatively, infants' event representations may differ in nature from the semantic structures of language, and thus, language learning may involve shaping pre-verbal thought (e.g., Choi, McDonough, Bowerman, & Mandler, 1999; Tomasello, 2003).

Despite these differences, what many theories have in common is the idea that infants' pre-verbal representations, to some extent, support language learning. As Mandler (2012) explains:

> "the spatial conceptual system is also adequate to enable early word understanding – names of things and places, spatial relations, and verbs describing various motion through space (see Mandler, 2005 for details). Needless to say, this view of early concept formation does not speak to the innate source of language itself; it only says that given a capacity for language, the early spatial system provides sufficient conceptual resources to get it started" (page 443).

One aim of the current study is to provide a systematic exploration of infants' "conceptual resources". To do so we consider two well-studied semantic structures in language – goal and source paths – and test whether infants conceptualize these paths abstractly such that they can support acquisition of the semantic structure of these paths in language. To date, studies testing how

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http://dx.doi.org/10.1016/j.cognition.2017.04.003
0010-0277/

infants represent spatial relationships have focused almost exclusively on specific relations, such as containment and support, above and below, and, tight and loose fit (Casasola, 2008; Choi, 2006; Quinn, 1994). Yet, few (if any) studies have tested whether infants represent spatial relations at a more general, arguably abstract level – a level akin to the superordinate level of object categorization. Testing this question is not only critical for understanding how spatial paths are represented in infancy, but also for understanding how infants' event representations could support learning the semantic roles of events that is necessary for language development.

1.1. Goal and source paths in linguistic theory

Talmy (1985) proposed that motion events (e.g., girl skipping out of school and into a sandbox) can be understood in terms of several core components: the object that undergoes motion (i.e., figure, the girl), the motion itself (skip), and the paths over which the figure moves (out of school, into sandbox). Further, paths can be understood in terms of various types, including source paths (i.e., from path + reference object), in which the figure moves away from an object that is its starting point (out of school) and goal paths (i.e., to path + reference object), in which the figure moves towards an object that is its endpoint (into a sandbox) (Jackendoff, 1983). In English, goal paths are encoded with prepositions such as "to", "in", "into", "on", and "onto" and source paths are encoded with prepositions such as "from", "out", and "off".

Critical to the current study is the observation that language encodes different events with parallel linguistic structures and this holds cross-linguistically. This was formalized by Jackendoff's Thematic Relations Hypothesis (Jackendoff, 1983). For example, the events of a girl skipping INTO a sandbox and a girl hopping ONTO a trampoline both include a goal path in semantic structure, despite the fact that one event depicts the girl moving *into* another object (containment relationship) and the other depicts the girl moving *onto* another object (support relationship). Similarly, the events of a girl running OUT OF school and a girl hopping OFF OF a trampoline both include a source path (Jackendoff, 1983). These parallel linguistic structures extend to events across very different domains, such as transfer, attachment/detachment, and change of state – domains that are less spatial than manner of motion events (see Lakusta & Landau, 2005 for an extended discussion).

1.2. Goal and source paths in language development

Given the abstract notions of goal and source paths in linguistic theory (i.e., the proposal for broad semantic roles), the question arises whether children's representations of goal and source paths are also abstract, and if so, to what extent. Studies in language acquisition shed some light on this question. Recent studies suggest that children and adults prefer to map goal paths over source paths into prepositional phrases, and that this mapping bias applies quite generally to a variety of spatial paths and across different event domains (Lakusta & Landau, 2005, 2012) For example, Lakusta and Landau (2005) reported that when 3- to 4-year-old children watched simple motion events (e.g., a plane flies out of a bowl and into a pot), and were then asked to describe them, they mentioned goal paths ("into the pot") more often than source paths ("out of the bowl"). This pattern was also observed for motion events depicting a figure moving 'out' and 'into', 'off' and 'onto', and 'away from' and 'next to' (see also Lakusta & Landau, 2012) and extended to non-manner of motion events as well, such as attachment/detachment (e.g., hook/unhook), change of possession events (e.g., give/get), and change of state events (e.g., change, turn) (Lakusta & Landau, 2005).

Further, studies by Clark and Carpenter (1989a, 1989b) suggest that children go through a period in development where they mark different types of starting points all with the locative marker "from", and sometimes this marking is used non-conventionally. For example, in spontaneous speech, a two-year-old child uttered, "These fall down from me", to describe an event where he pushed pieces of sandwich off of his plate (Clark & Carpenter, 1989a, p. 350). In this example, although the child is the agent, he is marking himself with the locative source marker "from". Further, in an empirical study, when 2.5- to 6-year-olds were asked to imitate and, if needed repair, passive sentences (e.g., "Dan got chased by a big snake"), 2-year-olds produced the locative source marker "from" rather than "by" (e.g., rather than repeating, "Dan got chased by a big snake" a child may say "Dan got chased from a big snake") (Clark & Carpenter, 1989b). Clark (2001) explains that these errors are evidence for an 'emergent category' of source; "certain phenomena in early language acquisition suggest that some conceptual categories may surface in children's speech even when they are not supported by the ambient language. These phenomena offer evidence for a set of general conceptual categories underlying language" (page 379).

These findings suggest that at least in early language, children may represent the semantic roles of goal and source path as they are understood in semantic structure (as broad and abstract semantic roles). The current study provides a direct test of whether infants conceptualize goal and source paths at this more general, abstract level by testing whether they categorize different specific goal paths (moving 'to', 'onto', 'into') as belonging to the general category, 'goal path' and the same for source paths (moving 'from', 'off', 'out'). In order for pre-verbal representations of goal paths and source paths to support acquisition of these semantic structures in language, infants should categorize across these different specific spatial relations. The current study is the first to provide a direct test of this hypothesis.

1.3. Infants' representations of paths

Perceiving a component of an event is a necessary prerequisite to forming a categorical representation of the component (see Göksun, Hirsh-Pasek, & Golinkoff, 2010; Golinkoff & Hirsh-Pasek, 2008 for a discussion), although it is not sufficient for claiming that infants possess the category. Indeed, recent research has shown that infants perceive all three kinds of paths put forth by Jackendoff (1990) – goal, source, and via paths. By 14 months infants discriminate via paths (over vs. under) (e.g., Pulverman, Golinkoff, Hirsh-Pasek, & Sootsman, 2008; Pulverman, Song, Golinkoff, & Hirsh-Pasek, 2013) and by 10 months they can detect an invariant via path (Pruden, Roseberry, Goksun, Hirsh-Pasek, & Golinkoff, 2013; also see Konishi, Pruden, Golinkoff, & Hirsh-Pasek, 2014 for an extension of these results). By 12 months infants encode goal and source paths (e.g., into a bowl vs. onto a box; out of a bowl vs. off of a box) (Lakusta & Carey, 2015; Lakusta, Wagner, O'Hearn, & Landau, 2007; Reardon, Lakusta, Muentener, & Carey, 2009; Wagner, 2009). In these latter studies 12-month-old infants were familiarized to a figure (animate-like, stuffed duck/agentive balloon) moving to one of two goal objects (e.g., into a bowl vs. onto a block). After familiarization, the locations of the goals were switched and infants viewed the objects in their new locations. During test, infants viewed either the figure move to the *same goal object in a new location* (into a bowl) or to a *different goal object in the same location as familiarization* (onto a block). Infants looked longer at the test trials where the figure moved to a different goal than when the figure moved to the same goal but in a different location compared to familiarization. This suggests that, during familiarization, infants attended to and represented the goal path in these motion events, and during test they were more surprised when the figure moved to a different goal. Further findings suggested that when the source objects were made sufficiently 'salient' (relatively large in size and multi-colored) infants also represent the source path; and they preferentially attend to the goal over the (salient) source when the two were pitted up against each other (Lakusta & Carey, 2015; Lakusta et al., 2007).

Although these findings suggest that infants perceive goal and source paths in motion events, they do not test whether infants represent goal and source paths as general concepts that encompass the relevant specific spatial relationships ('in', 'on' and 'to' for goal path, and 'out', 'off' and 'from', for source path). The studies pertinent to this question are studies testing whether infants categorize the specific goal paths, 'in' and 'on' (Casasola & Cohen, 2002; Casasola, Cohen, & Chiarello, 2003; Hespos & Spelke, 2004; McDonough, Choi, & Mandler, 2003; see Casasola, 2008 for a review). For example, Casasola et al. (2003) habituated 6-month-old infants to four different dynamic events depicting the spatial relation 'in' (e.g., a hand places a peg in yellow block, monkey in basket, etc.) and then tested infants with events including novel objects in the familiar relation (e.g., cup in dog bowl) versus novel objects in an unfamiliar relation (e.g., turtle on another turtle). Infants looked longer at the novel relation, suggesting that they categorized the containment relation. It is not until 18 months that infants are able to form categories for support ('on'), and even at this age, the category is concrete; infants do not generalize the support relation unless the events include the same objects (Casasola & Cohen, 2002) or unless the task is simple and only includes a few exemplars of the spatial relationship. Under these latter conditions, infants as young as 14 months can categorize support (Casasola, 2005b).

The presence of abstract concepts for IN and ON in pre-verbal infants raises the question of whether infants also represent the broader concept of GOAL PATH. One possibility is that the more general concept of GOAL PATH co-exists or maybe even precedes the categorization of the more specific goal paths involving containment and support. This possibility seems consistent with Mandler's (1992, 2004) proposal that infants represent relationships in rather general 'image schematic' formats that embody properties suitable for mapping into language. The current study tests this possibility.

1.4. The current study

In the current study we test whether infants have a general concept of GOAL PATH by familiarizing infants to motion events depicting a figure moving 'onto' and 'next to' a reference object and testing whether infants generalize to a different goal path – moving 'into' a reference object. The test of source path categorization was exactly the same except the paths that infants were familiarized to depicted a figure moving 'off of' and 'away from' a reference object.

In Experiments 1 and 2, we explore goal and source path categorization of motion events in 14.5-month-old infants. By 14.5 months, children represent specific goal paths and source paths in motion events (Lakusta et al., 2007; Lakusta & Carey, 2015), and detect invariant via paths (Pruden et al., 2013), manners (Pruden, Göksün, Roseberry, Hirsh-Pasek, & Golinkoff, 2012) and reference objects (Göksun, Hirsh-Pasek, & Golinkoff, 2014) in motion events. Thus, this is an age in which infants have been shown to represent the language-relevant components of motion events and thus, by hypothesis, may also form more abstract categories for them. Further, by 14.5 months infants categorize the more specific relationships of containment (Casasola & Cohen, 2002; Casasola et al., 2003) and support (under some conditions; Casasola, 2005b; Casasola & Cohen, 2002), thus increasing the likelihood that by 14.5 months infants may form the broader category.

In Experiment 3 we focus on goal path representations – the path most robustly represented by infants in Experiment 1. We provide a conceptual replication of the 14.5-month-old categorization findings reported in Experiment 1, as well as test younger infants – infants 10-months of age who have not yet acquired the relevant goal path terms in English ("to", "in", "on", "into", and "onto"). Exploring categorization at 10 months is critical for evaluating the hypothesis that pre-verbal infants' representations of goal paths supports the acquisition of a goal path semantic structure in language (e.g., whether a one to one mapping is possible).

2. Experiment 1: goal and source path categorization

2.1. Method

2.1.1. Participants

Thirty-nine infants were randomly assigned to one of three conditions. Thirteen infants participated in the Goal path familiarization condition (8 males; Mean age = 14 months, 17 days; Range: 14 months, 1 day to 14 months, 29 days) and thirteen infants participated in the Source path familiarization condition (6 males; Mean age = 14 months, 14 days; Range: 13 months, 29 days to 14 months, 27 days). Thirteen infants participated in the Baseline condition (6 males, Mean age = 14 months, 18 days; Range 14 months, 8 days to 15 months). Data from an additional five infants were not included in the final sample because of experimenter error (n = 3), fussiness before the test trials started (n = 1), and an interruption during the first test trial pair (n = 1).

2.1.2. Stimuli

Infants were shown motion events that were created in Adobe Flash. The motion events depicted a figure (duck or plane) moving from a source object *or* to a goal object. There were four familiarization events (Fig. 1) and six test events (Fig. 2); each event was 5.45 s in duration. All events began with an animated curtain opening (0.5 s). Then, for the events including goal paths, a figure emerged from behind the animated curtain and walked (2.0 s) to a goal object. It remained next to, on, or in the goal object (2.3 s). The animated curtain then closed (0.5 s) and remained closed (0.15 s). The events including source paths were *exactly* the same as the goal events except the figure moved away from an object that was its starting point and ended up behind the animated curtain.

2.1.2.1. Familiarization events. In all four familiarization events the figure object was a duck. The duck's trajectory of motion was from (to) the front or back corner of the animated stage to (from) the opposite corner (e.g., duck emerged from front-left of stage and walked to the tree which was located back-right of stage; Fig. 1). Thus in the familiarization events the duck took a diagonal path across the stage. Two of the familiarization events depicted an animated duck moving *to (from)* an endpoint (starting point) object and two depicted an animated duck moving *onto* (*off of*) an endpoint (starting point) object (Fig. 1). These four different familiarization events were strung together four times to yield four different familiarization trials (e.g., Familiarization trial 1: duck walks onto (or off) a box, duck walks to (or from) a tree, duck walks to (from) mailbox, duck walks onto (off) the block; Fig. 1). The order in which the familiarization events were strung together for each familiarization trial was random with the constraint that each event (e.g., onto a box, to a tree, to a mailbox, and onto a block) was presented first in the sequence for one familiarization trial. This ensured that infants would view each familiarization event at least once over the course of familiarization, and thus,

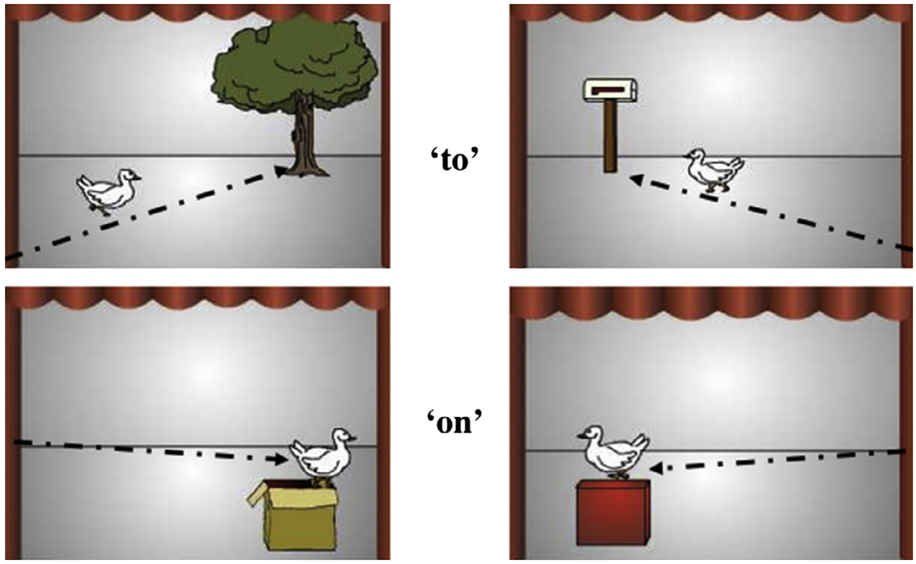

Fig. 1. Four familiarization events for the Goal path familiarization condition in Experiments 1 and 3. *Note:* The familiarization events for the Source path familiarization condition were exactly the same except the duck walked away from/off of the objects and ended up behind the animated curtain. Note that the reference objects were the same for both conditions except in the Goal path familiarization they were endpoints and in the Source path familiarization they were starting points.

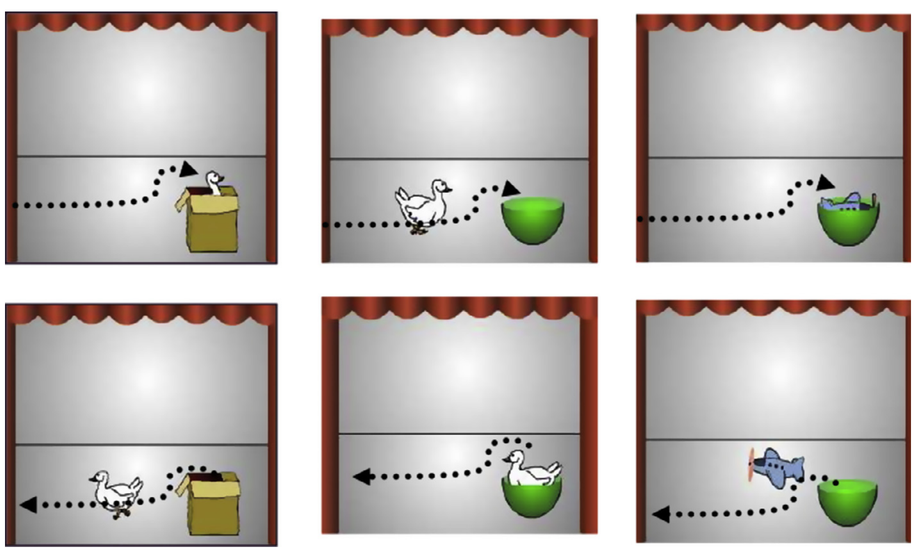

Fig. 2. Test events for infants in Experiment 1. *Note:* In half of the test events the reference objects were located on the right side of the stage, and in half of the test events the reference objects were located on the left side of the stage. The objects were always located on the opposite side in which the figure began its motion. In all the test trials the figure's trajectory of motion was from the middle (neither front nor back) of the stage to the opposite side of the stage.

that infants would not be familiarized to one specific spatial relationship (e.g., 'on' or 'off'), but rather would be familiarized to two different exemplars of goal (source) paths (e.g., 'on' and 'next to' or 'off' and 'away from'). Within each familiarization trial, the sequence of familiarization events was repeatedly presented (looped presentation) until the infant looked away for 2 continuous seconds or until 60 s had elapsed, which marked the end of the familiarization trial.

2.1.2.2. Test events

Three test events depicted a figure (duck or plane) moving into a goal object and three test events depicted a figure moving out of a source object. For all test events the figure's trajectory of motion was from (to) one side of the animated stage to (from) the opposite side, where a goal (source) object was located (e.g., duck emerged from behind the animated curtain on the left side of the stage and walked into a box which was located on the right side of the stage; Fig. 2). Thus, unlike the familiarization events, in the test events the figure's path was straight across the stage from one side to another. Whether the goal (source) objects were located on the right or left side of the stage was counterbalanced across infants. One test event constituted one test trial. The test event was repeatedly presented (looped presentation) within the test trial until the infant looked away for 2 continuous seconds or until 60 s had elapsed, which marked the end of the test trial. The order of presentation of the test events (goal or source path presented first) was counterbalanced across infants and the events were presented sequentially.

2.1.3. Design

2.1.3.1. Goal and source path familiarization conditions

Infants were randomly assigned to one of three conditions: Goal path familiarization (henceforth 'fam'), Source path fam, or Baseline. The design for the Goal and Source path fam conditions is shown in Table 1. The logic motivating this design is as follows: If infants categorize goal paths in motion events broadly across different specific goal paths, then after being familiarized with goal paths 'to' and 'onto', they should generalize to a novel goal path ('into') but not to a novel source path ('out'). Similarly, if infants categorize source paths in motion events broadly across different specific source paths, then after being familiarized with source paths 'from' and 'off', they should generalize to a novel source path ('out') but not to a novel goal path ('into'). Note that the familiarization events were exactly the same in each condition except that in the Goal path condition the reference objects were endpoints and in the Source path condition the reference objects were starting points. Further, the test events were exactly the same for the Goal path and Source path fam conditions.

Since our primary research question is whether infants have general, abstract concepts for goal and source paths, we wanted to test *the extent* to which infants would generalize the spatial relation viewed during familiarization (goal or source path) to a novel relation of the same type during test ('into' if familiarized to 'onto' and 'to', and 'out of' if familiarized to 'off' and 'from'). That is, could infants generalize representations of 'onto' and 'to' not only to highly similar events portraying 'into', but also to 'into' events that had different reference objects and/or figures? And, the same question holds for source paths. Thus, in order to test the extent of generalization, as shown in Fig. 2, the three test trial pairs differed in how similar they were to the familiarization events. Pair 1 had the same figure (duck) and reference object (box) as one of the familiarization events, but novel spatial relationship (containment), Pair 2 had the same figure (duck) as the familiarization events, but novel spatial relationship (containment) and reference object (bowl), and Pair 3 had a novel spatial relation (containment), reference object (bowl), figure (airplane), and motion (fly) compared to familiarization.

Further, since this was our very first test of infants' goal and source path categorization abilities, the experiment was designed such that infants had the best chance for success. Findings suggest that infants find it easier to categorize spatial relations when the test objects in the events are the same as those presented during a familiarization phase (e.g., Casasola & Cohen, 2002; Quinn, Cummins, Kase, Martin, & Weissman, 1996; see also Casasola, 2008). Thus, in the current experiment, we presented infants with the three test trial pairs in a fixed order. The goal and source test events that were most similar to the familiarization events were presented first as Pair 1, and the goal and source test events that were least similar to the familiarization events were presented last as Pair 3 (see Table 1 and Fig. 2).

Four additional trials were interspersed among the test events, two re-familiarization trials and two exposure trials (Table 1). Each re-familiarization trial was one of the familiarization trials that the infant viewed during the familiarization phase; these were included to provide infants with another opportunity to view the type of spatial path that they viewed during familiarization (goal or source path). The exposure trials were provided to acquaint infants with the novel objects (bowl and plane) that would be shown to them in the subsequent test trial (such exposure trials are common in infant looking time studies; e.g. Woodward, 1998). Similar to the other trials, both the re-familiarization and exposure trials were repeatedly presented (looped presentation) until the infant looked away for 2 continuous seconds or until 60 s had elapsed, which marked the end of the trial.

2.1.3.2. Baseline condition

If infants form a categorical representation of goal path and/or source path during familiarization, then they should show a preference for the novel category exemplar as has been shown in other studies exploring infant categorization (e.g., Quinn, 1994). However, this prediction holds *only* if infants find the test events equally salient prior to familiarization (i.e., show no baseline preference for the goal path vs. the source path test trials). Yet, previous research suggests that infants by 12 months of age preferentially encode goal over source paths (Lakusta & Carey, 2015; Lakusta et al., 2007), thus raising the strong possibility that infants may show a baseline preference for the goal path test events (e.g., the duck moves into the box) over the source path test events (e.g., the duck moves out of the box). In order to explore this possibility, we presented another group of infants (Baseline condition) with only the goal path and source path test events; they did

Table 1
Design of Study 1: Goal Path Familiarization Condition.

Familiarization[a]	
Familiarization Trial 1	Duck walks onto box, duck walks to tree, duck walks to mailbox, duck walks onto block
Familiarization Trial 2	Duck walks to tree, duck walks onto box, duck walks onto block, duck walks to mailbox
Familiarization Trial 3	Duck walks to mailbox, duck walks onto block, duck walks to tree, duck walks onto box
Familiarization Trial 4	Duck walks onto block, duck walks onto box, duck walks to mailbox, duck walks to tree
Test Trial Pair 1 (novel spatial relation)	
Goal Path Event	Duck walks into a box
Source Path Event	Duck walks out of a box
Re-familiarization Trial	Duck walks onto box, duck walks to tree, duck walks to mailbox, duck walks onto block
Exposure Trial	Static bowl
Test Pair 2 (novel spatial relation and reference object)	
Goal Path Event	Duck walks into a bowl
Source Path Event	Duck walks out of a bowl
Re-familiarization Trial	Duck walks to tree, duck walks onto box, duck walks onto block, duck walks to mailbox
Exposure Trial	Plane flying in circles
Test Pair 3 (novel spatial relation, reference object, figure, and motion)	
Goal Path Event	Airplane flies into a bowl
Source Path Event	Airplane flies out of a bowl

Notes. The Source Path Familiarization Condition had exactly the same design, except the infants were familiarized to events with source paths rather than goal paths: duck walks off of a box, duck walks from a tree, duck walks from a mailbox, duck walks off of a block.

[a] The four different familiarization events were strung together four times to yield four different familiarization trials (one example is presented in the table above).

not receive familiarization with motion events including goal or source paths. Rather, prior to the test trials they only viewed the following three events: a red stationary box, followed by two trials depicting a duck walking around in circles. This was done in order to familiarize these infants with the objects that they would view in the subsequent test events. The test events and exposure trials were exactly the same as those used for the Goal path and Source path fam conditions (see Table 1).

If infants show a baseline preference for goal path events, then it will be essential to take this baseline preference into account when analyzing the looking times for the infants who were familiarized with goal paths and source paths.

2.1.4. Procedure

The stimuli were presented on a projection screen. The infant sat on their caregiver's lap about two feet in front of the screen. The parent was asked to close his or her eyes for the duration of the experiment. The infant's looking time at the screen was recorded by a trained observer. The observer watched the infant on a computer monitor and pressed a key on a computer keyboard whenever the infant looked at the computer screen. Looking time was not recorded until the infant looked at the event for at least 2.5 continuous seconds; this ensured that the infant viewed the first event in each familiarization trial. A computer program (Xhab) calculated the infant's looking time (Pinto, 1994). When the infant looked away from the computer screen for 2 continuous seconds, or until 60 s had elapsed, the computer program beeped to signal to the experimenter to proceed to the next trial. The experimenter lowered (raised) the curtain at the end (beginning) of each familiarization and test trial.

In order to assess coding reliability, 100% of the infants in the Goal path and Source path fam conditions, and 85% of the infants in the Baseline condition were coded on-line by a second trained observer. Average percent agreement between coder one and coder two was calculated by Xhab (Xhab samples the inputs from the two coders every 100 ms and computes observer reliability based on whether during each time slice the two coders were both coding the infant as looking at or away from the stage). Average inter-observer agreement was 0.95, 0.94, and 0.95, for the Baseline, Goal path, and Source path conditions, respectively.

2.2. Results

2.2.1. Is there a baseline preference for goal path vs. source path events?

The first analysis tested whether infants in the Baseline condition showed a preference for goal paths over source paths. If they did, then subsequent tests of goal and source path categorization would need to take this baseline preference into account.

Infants in the Baseline condition showed a preference for goal path events over source path events. Looking times were averaged across test trials and showed that infants looked longer at the goal path events ($M = 37.58$; $SE = 4.42$) compared to source path events ($M = 18.83$; $SE = 3.05$), paired-t $(12) = 5.14$, $p < 0.001$, 2-tailed. Thus, similar to previous findings (Lakusta & Carey, 2015; Lakusta & DiFabrizio, 2016; Lakusta et al., 2007), infants showed a bias for goal path events over source path events.[1]

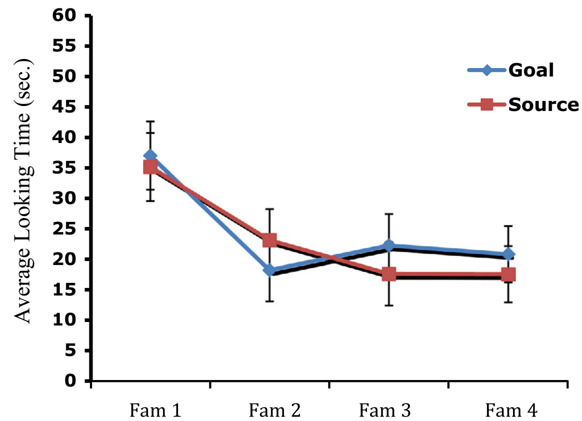

Fig. 3. Average looking times (and *SE*s) at the four familiarization trials for the Goal path fam and Source path fam conditions of Exp. 1.

2.2.2. Familiarization

The next analysis examined whether infants in the goal and source path familiarization conditions looked at the familiarization events to a similar extent (see Fig. 3). A 4 (Familiarization trial: 1–4) × 2 (Condition: Goal path fam, Source path fam) mixed ANOVA on infants' raw looking times during the familiarization trials yielded a significant main effect of familiarization trial, $F\ (3, 72) = 6.90$, $p < 0.001$, $\eta_p^2 = 0.22$. Infants' looking times declined over familiarization, suggesting that they encoded the events (*M*s. and *SE*s for trials 1–4, respectively = 36.10 (3.96), 20.74 (3.58), 20.01 (3.66), 19.26 (3.25)). There was no significant main effect of condition nor was there a significant interaction between familiarization trial and condition ($Fs < 0.47$, $ps > 0.05$), suggesting that the rate of familiarization across the two conditions did not significantly differ.[2]

2.2.3. Test trials

Given the baseline preference for goal path events reported above, the next analysis explored whether there were any significant differences in how infants in the three different conditions (Baseline, Goal path fam, Source path fam) looked at the source and goal paths test events. If those infants familiarized with goal (source) paths categorized the paths, then infants in these Goal and Source path fam conditions should show different patterns of looking at the goal/source path test events than those infants in the Baseline condition (because these infants were not familiarized to goal/source paths).

A 3 (Condition: Baseline, Goal path fam, Source path fam) × 3 (Trial Pair: one, two, three) × 2 (Test Trial Type: Goal path, Source path) mixed ANOVA on infants' raw looking times during the test trials yielded significant main effects of test trial pair, $F(2, 72) = 14.96$, $p < 0.001$, $\eta_p^2 = 0.29$, test trial type, $F(1, 36) = 65.57$, $p < 0.001$, $\eta_p^2 = 0.65$, and condition $F(1, 36) = 5.28$, $p = 0.01$, $\eta_p^2 = 0.28$. However, these main effects were subsumed by significant interactions between test trial pair and test trial type $F(2, 72) = 5.34$, $p = 0.007$, $\eta_p^2 = 0.13$ and, notably, between condition and test trial type, $F(2, 36) = 10.40$, $p < 0.001$, $\eta_p^2 = 0.37$. The three-way interaction between condition, test trial pair, and test

[1] The finding that this asymmetry is based on infants representing the events as a motion event involving a figure moving *to/from a goal/source object* is supported by data from a control experiment in our lab in which the source and goal objects were removed from the events in the Baseline condition. Thus the events only showed the duck 'appearing' and 'disappearing' behind the curtain. Infants (n = 16) did not look significantly longer at the duck 'appearing' events ($M = 15.81$, $SE = 2.18$) than the duck 'disappearing' events ($M = 12.88$, $SE = 2.26$; paired-t $(15) = 1.60$, $p > 0.10$, 2-tailed).

[2] Although there was no significant difference in the rate of familiarization between the two conditions, consistent with previous research (e.g., Lakusta & DiFabrizio, 2016), the patterns of the means suggests that infants is the goal path condition looked slightly longer at the goal path events than infants in the source path condition looked at the source path events (Fig. 3). Given that each familiarization trial was comprised of four different dynamic events, it is perhaps not surprising that infants in both conditions were attentive to the events.

Table 2
Average Looking Times (and *SE*s) in seconds at Goal and Source Path Test Events for Test Trial Pairs 1, 2 and 3 for Each Condition in Experiment 1 and Experiment 2.

Test trial type	Test trials pair 1		Test trials pair 2		Test trials pair 3	
	Goal path	Source path	Goal path	Source path	Goal path	Source path
Experiment 1						
Baseline	48.18	24.91	36.55	11.41	28.03	20.17
	(4.09)	(5.38)	(5.76)	(1.73)	(5.63)	(5.32)
Goal Path fam	24.99	18.05	16.63	16.42	12.05	9.80
	(5.56)	(4.86)	(2.37)	(2.46)	(2.54)	(1.99)
Source Path fam	48.05	18.19	35.32	14.30	25.32	10.15
	(5.85)	(3.64)	(4.49)	(4.03)	(5.05)	(2.59)
Experiment 2						
Baseline	39.79	23.34	25.75	23.15	23.02	21.29
	(6.30)	(5.38)	(5.26)	(5.10)	(5.68)	(4.05)
Salient source fam	38.29	18.92	34.62	14.34	30.63	10.67
	(5.72)	(3.49)	(5.94)	(3.37)	(4.88)	(1.92)

trial type was not significant ($p = 0.24$) nor was the interaction between condition and test trial pair ($p = 0.61$) (see Table 2).

In order to further explore the significant interaction of condition and test trial type, two separate, 2 condition by 2 test trial type ANOVAs were performed; if infants categorized goal paths, then infants familiarized with goal paths should show a different pattern of looking at the test events compared to infants in the baseline condition. The same holds for categorization of source paths. For infants familiarized with goal paths, this prediction was supported with a significant interaction between condition and test trial type, $F(1, 24) = 13.46$, $p = 0.001$, $n^2_p = 0.36$. As shown in Fig. 4, the preference for goal paths over source paths was less for the infants familiarized with goals path events than for infants in the Baseline condition, suggesting categorization; infants generalized the goal path events viewed during familiarization to the new goal path events shown during test. In contrast, the interaction between condition and test trial type was *not* significant for infants familiarized with source paths ($p = 0.52$), but there was a main effect of trial type, $F(1, 24) = 67.60$, $p < 0.001$, $n^2_p = 0.74$; infants looked longer at the goal path events than the source path events (Fig. 4). The main effect of condition was not significant. Thus, infants familiarized with source path events show no evidence for categorizing the source paths. Additional analyses explored whether sex and side that the reference objects were located in the events (left or right) interacted with Trial Type and Condition. None of these interactions were significant (*ps* > 0.10).

The results thus far suggest that 14.5-month-old infants form categorical representations of goal paths in motion events, but not of source paths. However, it is possible that, compared to infants in the Baseline condition, infants in the Goal path fam condition showed a different pattern of looking at the test events not because they were generalizing the goal paths that they viewed during familiarization to the novel goal paths that they viewed during the test events, but rather because they received familiarization in general, and lost interest by the time they viewed the test trials. In order to rule out this possibility a 2 (Condition: Goal path fam, Source path fam) × 2 (Test Trial Type: Goal, Source) ANOVA was performed and yielded a significant interaction, $F(1, 24) = 22.19$, $p < 0.001$, $n^2_p = 0.48$. Infants familiarized with goal path events indeed showed a different pattern of looking at the goal vs. source path test events than infants familiarized with source path events, providing further evidence for goal path categorization.

The results from Experiment 1 do not provide any evidence that infants categorized the source paths over the familiarization events. One possibility is that infants did not categorize the source paths because they did not attend to and encode the source object and its path during the familiarization events. This explanation receives support from findings reported by Lakusta et al. (2007)

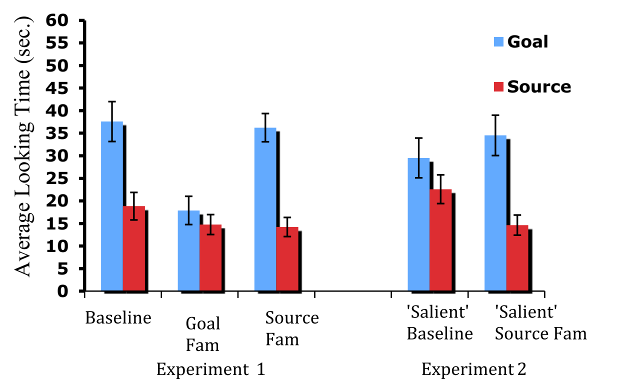

Fig. 4. Average looking times (and *SE*s) at the two different trial types (goal path vs. source path) for the conditions in Exp. 1 (Baseline, Goal path fam, Source path fam) and Exp. 2 (Salient Baseline and Salient Source path fam).

who found that 12-month-old infants only show evidence of representing (i.e., discriminating) source paths in motion events if the source objects are made ‘salient’ (e.g., big and bright.). We explore this in Experiment 2, by familiarizing infants with motion events that included source objects that were bigger in size and more colorful compared to the objects used in Experiment 1. Infants were then tested on novel events that depicted goal or source paths, and these events also included the ‘salient’ reference objects. If the failure to find evidence for source path categorization in Experiment 1 can be explained by infants failing to attend to and encode the source path during familiarization, then making the source reference objects more physically salient may lead infants to encode the source paths, and henceforth categorize them.[3]

3. Experiment 2: salient source path categorization

3.1. Method

3.1.1. Participants

Twenty-six infants were randomly assigned to one of two conditions. Thirteen infants participated in the Salient source path familiarization condition (8 males; Mean age = 14 months,

[3] It’s interesting to note that despite the differences in categorization of goal and source paths reported for this Experiment, the comparison of infants’ looking times at these paths during familiarization suggests that they look at the events for relatively the same amount of time. Future eye-tracking studies examining precisely what aspects of the events infants’ attend to would elucidate how infants process the source vs. goal path events. For example, perhaps infants look more at the reference object in the goal path events than the source path events.

Fig. 5. Test events for infants in the Salient Source Fam and Baseline conditions in Experiment 2.

17 days; Range: 14 months to 15 months, 5 days) and thirteen infants participated in the Baseline condition (5 males, Mean age = 14 months, 15 days; Range: 14 months to 15 months, 5 days). Data from an additional five infants were not included in the final sample because of experimenter error (n = 1), and fussiness before the test trials started (n = 4).

3.1.2. Stimuli

The stimuli were exactly the same as those used in the Source path and Baseline conditions of Experiment 1, except that all the reference objects (i.e., the source objects during the familiarization events as well as the source and goal objects in the test events) were made more salient (Fig. 5).

3.1.3. Design and procedure

The design and procedure were exactly the same as those in Experiment 1, except there were two rather than three conditions: Salient source familiarization (Salient source path fam) and Baseline. In order to assess coding reliability, 100% of the infants in the Salient source path fam and Baseline conditions were coded on-line by a second trained observer. Average inter-observer agreement was 0.94 and 0.95, for the Salient source path and Baseline conditions, respectively.

3.2. Results

3.2.1. Baseline condition

Infants in the Baseline condition showed a preference for goal path events over source path events (Fig. 4), despite the increased salience of the reference objects. Looking times were averaged across test trials and showed that infants looked longer at the goal path events ($M = 29.52$; $SE = 4.41$) compared to source path events ($M = 22.59$; $SE = 3.18$), paired-$t(12) = 2.50$, $p = 0.03$, 2-tailed.

3.2.2. Salient source path familiarization

The infants' looking times decreased from the first to the fourth familiarization trials (*Ms.* = 33.50, 16.45, 26.85, 19.37; *SEs* = 5.64, 4.27, 5.31, 4.25), for trials one to four, respectively, $F(3, 36) = 3.35$, $p = 0.03$, $n_p^2 = 0.22$.

As in Exp. 1, in order to explore categorization, the next analyses explored whether infants familiarized with source path events showed a different pattern of looking at the goal and source path test events than those infants in the Baseline condition. A 2 (Condition: Baseline, Salient Source path fam), × 3 (Trial Pair: one, two, three), × 2 (Test Trial Type: Goal, Source) mixed ANOVA on infants' raw looking times during the test trials yielded a significant main effect of test trial pair, $F(2, 48) = 5.56$, $p = 0.007$, $n_p^2 = 0.19$, reflecting that collapsed over the two conditions, infants looking decreased from test trials one to three (*Ms.* = 30.09, 24.46, 21.40; *SEs* = 3.04, 2.79, 2.63). There was also a significant main effect of test trial type, $F(1, 24) = 39.01$, $p < 0.01$, $n_p^2 = 0.62$ and notably, the interaction between condition and test trial type was significant, $F(1, 24) = 9.10$, $p = 0.006$, $n_p^2 = 0.275$. Infants familiarized with source path events showed a significantly different pattern of looking at the goal and source path test events than infants in the Baseline condition (Fig. 4). There were no other significant main effects or interactions ($ps > 0.10$). Additional analyses explored whether sex and side that the reference objects were located in the events (left or right) interacted with Trial Type and Condition. None of these interactions were significant ($ps > 0.10$).[4]

The results from Experiment 2 suggest that when the source objects are 'salient', 14.5-month-old infants categorize source paths. Thus, not only do infants show an asymmetry between source and goal paths in how they attend to and remember them when representing a motion event (Lakusta & Carey, 2015; Lakusta & DiFabrizio, 2016; Lakusta et al., 2007), but they also show a difference in their ability to categorize them. We return to this finding in the General Discussion when we consider how pre-verbal conceptualizations of source paths may support language development.

4. Experiment 3: goal path categorization in 10-month-old infants

The finding reported in Experiment 1 - that 14.5-month-olds have a general concept of GOAL PATH - raises the critical question

[4] Inspection of the Baseline conditions in Exp. 1 vs. 2 (see Fig. 4 1st and 4th pair of bars) reveals that the goal bias for Exp. 1 was greater than the goal bias for Exp. 2; indeed a 2 (Event type: goal, source) × 2 (Exp.: Baseline ordinary objects, Baseline salient objects) ANOVA revealed a significant interaction, $F(1, 24) = 6.67$, $p = 0.02$. Perhaps increasing the salience of the objects in Exp. 2 led infants to attend to the reference objects in the events (which were the same) and less to the path types (source or goal). Still, infants familiarized with salient source paths in Exp. 2, looked less at the source paths during test ($M = 14.64$, $SE = 2.23$) compared to infants in the corresponding Baseline condition ($M = 22.59$, $SE = 3.18$); independent samples t-test: $t(24) = 2.05$, $p = 0.05$. This is consistent with the interpretation that infants categorize the source paths in Exp. 2.

of whether younger infants may also represent goal paths at this more general, abstract level. Testing younger infants is critical for determining whether a general concept of GOAL PATH exists prior to acquisition of the relevant spatial language that encodes goals (e.g., "to", "into", and "onto", in English). If so, then such a representation of goal path could map quite readily into semantic structure during language acquisition. Alternatively, it's possible that a general concept of GOAL PATH is acquired as the child is acquiring the relevant language. For example comprehending constructions such as "x jumps *into Y*", "x moves *onto Y*", "x ran *to Y* (all sentences including the semantic argument GOAL PATH, and in this case, also including the same preposition "to") may bootstrap children's broad concept of GOAL PATH (see Tomasello, 2003). Specifically it may lead children to align the similar semantic structures across the three different events (moving *into, onto* and *to*) yielding a general concept of GOAL PATH.

In order to explore these two possibilities, in Experiment 3, 10-month-olds were tested, and compared to another group of 14.5-month-olds. We tested infants at 10 months because research by Casasola and colleagues has shown that by 10 months infants can discriminate and even categorize some specific paths involving endpoints, such as containment and support (see Casasola, 2008 for a review). Yet, at 10 months, it is highly unlikely that infants are comprehending spatial language that encodes goal paths, such as "to" "into" and "onto". Indeed the Wordbank database (Frank, Braginsky, Yurovsky, & Marchman, in press) reports that it is not until 16 months of age that more than 50% of infants are reported to understand "on" (0.56) and "in" (0.54) on the MacArthur-Bates Communicative Development Inventory ("to", "into", and "onto" are not included on the MCDI). Thus 10 months is an ideal age to test the hypothesis that a broad concept of GOAL PATH precedes acquisition of the spatial terms encoding goal paths.

In addition to testing younger infants, Exp. 3 adopts a different methodology for testing goal path categorization. The method used in Experiment 1 involved testing a separate group of infants – the 'Baseline condition' - to assess any a priori differences in looking times at the test events. These results were then compared to the looking times at the test events for infants familiarized with goal paths. Even stronger evidence for path categorization would be to compare looking time at the test events before and after familiarization *within the same infant*. The Preferential Looking Paradigm (PLP) allows one to do just this. Thus, in Experiment 3 we adopt the PLP to test goal path categorization in 10-month-olds, as well as to provide a conceptual replication of the goal categorization results with 14.5-month-olds found in Experiment 1.

4.1. Method

4.1.1. Participants

Thirty 10-month-old infants (16 males; Mean age = 9 months, 27 days; Range: 9 months, 14 days–10 months, 18 days) and 30 14.5-month-old infants (16 males; Mean age = 14 months, 13 days; Range: 13 months, 25 days–14 months, 29 days) participated in the study.

4.1.2. Stimuli

The stimuli (familiarization and test events) were exactly the same as those in the Goal path condition for Experiment 1 with the exception that a monkey replaced the plane for one of the test trial pairs. A plane is likely perceived as less animate and less intentional than a duck, and although there were no significant differences found among the three test trial pairs, examination of the means (see Table 1) suggest that the plane events may have been processed differently than the duck events – a question which could be explored in future studies. Given this, for Exp. 3 another animal – a monkey- was included as the figure rather than a plane. Further, since the PLP is not infant-controlled in that progression to the next trial occurs after the infant looks away for a pre-specified amount of time, the events in this experiment played for a pre-set amount. The length of the events is described below.

4.1.3. Design

Following Pruden et al. (2013), the PLP was used to test goal path categorization. The design is depicted in Table 3. Note that unlike Experiment 1 in which infants viewed the three different test trial pairs after one main familiarization phase (see Table 1), in the current experiment, the three test trials were separated such that each was presented as it's own 'block'; this allowed us to meet the constraints of a PLP design. Table 3 displays the block for test pair A (henceforth, Block A). The categorization test for test trial pairs B and C (henceforth referred to as Block B and C, respectively) had the same design as that shown in Table 3. Importantly the familiarization events were the same for every block; only the test events differed for each block. Thus, Block A tested whether infants categorize goal paths for events with a different spatial relation ('in'); Block B tested whether infants categorize goal paths for events with a different spatial relation ('in') and a different reference object (bowl); Block C tested whether infants categorize goal paths for events with a different spatial relation ('in'), reference object (bowl) and figure (monkey). The order in which the blocks were presented was counterbalanced across infants (unlike Exp. 1 where the order of test trial pair presentation was fixed). Infants could participate all three blocks; however some infants fussed out after presentation of the first or second block. Thus, the number of infants participating in each block varied and is reported in the Results section below.

Each block included the four main phases that are typical of PLP designs testing categorization (e.g., Pruden et al., 2013): Introduction, Salience, Familiarization and Test (see Table 3).

Introduction phase: This phase consisted of two trials, one in which the events were presented on the left side of the screen

Table 3
Design of Experiment 3, Block A: Goal Path Categorization Using the Preferential Looking Paradigm.

Phase	Events	
	Left image	Right image
Introduction	Duck walks in circles	
		Duck walks in circles
Salience	Duck walks into box	Duck walks out of box
Familiarization		
Familiarization Trial 1[a]	Duck walks onto box, duck walks to tree, duck walks to mailbox, duck walks onto block	
Familiarization Trial 2	Duck walks to tree, duck walks onto box, duck walks onto block, duck walks to mailbox	
Familiarization Trial 3	Duck walks to mailbox, duck walks onto block, duck walks to tree, duck walks onto box	
Familiarization Trial 4	Duck walks onto block, duck walks onto box, duck walks to mailbox, duck walks to tree	
Test	Duck walks into box	Duck walks out of box

Note. The design for Blocks B and C were identical with the exception of the salience and test events: for Block B (novel spatial relation/novel reference object) the salience and test events displayed a duck moving into a bowl (goal path event) and a duck moving out of a bowl (source path event), for Block C (novel spatial relation/novel reference object/novel figure) the salience and test events displayed a monkey moving into a bowl (goal path event) and a monkey moving out of a bowl (source path event).

[a] Note that as previously described in the Method for Exp. 1, the four different familiarization events were strung together four times to yield four different familiarization trials (one example is presented in the table above).

and one in which they were presented on the right (Table 3). The aim was to show infants that the animated events would occur on both sides of the screen. During the Introduction phase, the animated curtain opened (0.5 s) and infants viewed the figure (duck or monkey) walk back and forth (4.3 s.) followed by the curtain closing (0.5 s.) and remaining closed (0.15 s). This event looped one time, thus the entire Introduction trial was 10.9 s. Then the same event appeared on the opposite side of the screen. The order of which side the event appeared was counterbalanced across infants.

Salience phase: This phase consisted of one trial in which infants viewed events identical to the events presented during the test phase (see below) to determine whether infants showed any a priori preferences for the test events. Infants viewed the two events playing simultaneously side-by-side.

Familiarization phase: This phase consisted of four trials; these were the same four goal path familiarization trials as described in Exp. 1 (see Fig. 1). Each event within the familiarization trial played once (5.45 s), to yield a total familiarization trial length of 21.8 s.

Test phase: In order to assess whether infants categorized the goal path events during familiarization, this phase presented infants with a novel in-category goal path event and a novel out-of-category source path event. Infants viewed the goal and source path test events simultaneously; the events (each 5.45 s) looped once for a total trial length of 10.9 s. Infants viewed two presentations of the test trials. Whether the goal or source path events appeared on the right or left side of the screen was counterbalanced across infants.

Centering stimulus: A centering stimulus was presented in between each trial to ensure that infants looked back at the center of the screen. The centering stimulus was a picture of a flashing baby's face accompanied by a 3 s audio clip from *The Baby Einstein Music Box Orchestra.*

4.1.4. Apparatus and procedure

These were the same as Exp. 1 with the exception that infants were seated on their caregivers' lap 4 feet away from a 40-in. television monitor set on top of a table.

Most parents (n = 41) in Exp. 3 completed the long form of the MCDI. Since prepositions marking goal paths were of particular interest in this study, the following prepositions were added to the section "Prepositions and Location": "into", "to", and "onto".

4.1.5. Coding, reliability, dependent variable, and predictions

Similar to other preferential looking studies (Swingley, 2011) the dependent variable was the first two seconds of infants' looking duration at each event. Since the videos are presented for a fixed amount of time in the PLP, infants' looking durations and directions (left, right, center, and away) were coded off-line using the software Datavyu (Datavyu Team, 2014). In order to calculate inter-coder reliability, for each infant, Datavyu generated coding cells for every 6th look over the course of the entire experiment. Then, an independent coder coded looking direction for these reliability cells and the output was compared to the original coder's output. This resulted in a mean reliability of $r > 0.966$ ($SD = 1.97$) for 10-month-olds and $r > 0.971$ ($SD = 1.97$) for 14.5-month-olds.

Following Pruden et al. (2013) a novelty preference score (NPS) was calculated for each infant by dividing the amount of looking at the source path event (out-of-category) by the sum of the looking time at source path event and goal path event (in-category). A preference score above 0.50 meant that the infant looked longer at the source path event, whereas a preference score below 0.50 meant that they looked longer at the goal path event. Given infants' preference for goal path events over source path events (Baseline condition of Exp. 1, Lakusta & Carey, 2015; Lakusta & DiFabrizio, 2016; Lakusta et al., 2007), a preference score was also calculated for the salience trials. To test categorization, we compared the NPS scores for salience and test. This provided a conservative test of our hypothesis. This method of analysis thus provides a within subject comparison of how long each infant looked at the source vs. goal path test events before and after familiarization to goal paths. If infants categorize the goal path over the course of the familiarization events, then they should look longer at the novel source path events during the test phase versus the salience phase. This is a conservative test because the results of Exp. 1 and previous research have shown that infants have a preference for goal path events. Thus, in order to show evidence for categorization they would need to 'overcome' this a priori preference.

4.2. Results

4.2.1. Language development

Table 4 reports the data for children's comprehension of the goal paths terms, "to", "into", and "onto". As predicted, comprehension of goal path terms is less than 50% for both 10- and 14.5-month-olds. Given this low level of comprehension of these terms at these ages (especially at 10-months) it is highly unlikely that any categorization of goal paths reported below can be explained by their understanding of the relevant spatial language.

4.2.2. Categorization

Given that each block provides its own test of categorization, the results for each block are presented separately below. Data for each age group and for each block were examined for outliers (z score > 2 SD). One 14-month-old's data was excluded for Block C because it was an outlier.

4.2.2.1. Block A: novel spatial relation (containment) compared to familiarization. Out of the 30 10-month-olds and out of the 30 14.5-month-olds who participated in this study, 21 10-month-olds (10 male) and 21 14.5-month-olds (12 male) participated in Block A. The remaining infants were excluded because of fussiness (i.e., excessive crying or refusing to sit on the caregiver's lap) and one 10-month-old looked away from the events during the entire salience trial.

Infants' looking times at the familiarization events were examined to test whether infants were familiarized to the events and whether there were any differences in how infants of the different ages attended to the events. A 4 (Familiarization Trial: 1–4) × 2 (Age: 10, 14.5) ANOVA yielded no significant interaction or main effects ($ps > 0.10$). Although the pattern of the means reveals that infants' looking duration at the events declined over the course of familiarization (Table 5), the differences among the trials were not significant.

Table 4
Proportion of children reported to understand "to", "into" and "onto" at 10 and 14.5 months.

Goal path terms			
Age (months)	To	Into	Onto
10	0.04	0.04	0.00
14.5	0.24	0.24	0.20

Note. Comprehension of the spatial terms "on" and "in" – terms often used to refer to static spatial relationships between objects was also measured; the proportion of children reported to comprehend "on" and "in" for 10- and 14.5-month-olds respectively was 0.26 ("on") and 0.19 ("in"), and 0.52 ("on") and 0.44 ("in"). These proportions are slightly higher than the proportions reported by Wordbank (Frank et al., in press); thus, our sample of parents may have overestimated their infants' knowledge of "to", "into", and "onto".

Table 5
Average looking times (and *SE*s) in seconds at the familiarization events for blocks A, B, and C for 10- and 14.5-month-old infants.

	Block A		Block B		Block C	
Age	10 months	14.5 months	10 months	14.5 months	10 months	14.5 months
Familiarization trial						
1	15.11	18.92	17.25	19.55	15.91	17.61
	(1.20)	(1.17)	(0.81)	(0.84)	(0.96)	(1.12)
2	13.85	17.19	21.95	17.71	13.74	17.80
	(1.36)	(1.36)	(4.38)	(4.56)	(0.95)	(1.11)
3	15.54	16.16	16.34	17.02	14.11	14.46
	(1.36)	(1.36)	(0.88)	(0.92)	(1.14)	(1.33)
4	13.89	16.02	16.19	15.64	13.28	17.17
	(1.22)	(1.22)	(0.94)	(0.98)	(1.06)	(1.24)

In order to test whether infants categorized the goal paths for Block A, a 2 (Trial Type: Salience, Test) × 2 (Age: 10, 14.5) ANOVA was conducted. This yielded no significant interaction or main effects (*F*s < 0.18, *ps* > 0.50; see Fig. 6), thus providing no evidence for categorization. However, additional analyses explored whether sex, side that the reference objects were located on in the events (left or right), and order of block presentation (1st, 2nd, or 3rd with respect to the presentation of the other blocks) interacted with trial type. None of these interactions were significant (*ps* > 0.10), with one exception. There was a significant three-way interaction between trial type, age, and sex, $F(1, 38) = 4.99$, $p = 0.03$, $\eta_p^2 = 0.12$ and a marginally significant trial type by sex interaction, $F(1, 38) = 4.14$, $p = 0.049$, $\eta_p^2 = 0.10$. The 10-month-old males and females and the 14.5-month-old males looked longer at the source path events during test compared to salience (reflecting the pattern displayed in Fig. 6 for Block A). However, the 14.5-month-old females showed the opposite pattern and looked longer at the source path events during salience (Mean NPS = 0.44, *SE* = 0.07) compared to test (Mean NPS = 0.20, *SE* = 0.20), possibly suggesting a familiarity effect. In order to explore this, we tested whether infants' looking times decreased from the first to the second half of the entire familiarization phase. Looking times at the first and second familiarization trials, and at the third and fourth familiarization trials, were averaged together and entered into a 2 (Familiarization Trial: 1 and 2 vs. 3 and 4) × 2 (Sex: male, female) × 2 (Age: 10, 14.5) ANOVA. This did not yield a significant three-way interaction ($p = 0.95$) as may be expected if the 14.5-month-old females' looking durations from the 1st to the 2nd half of familiarization differed from the other groups.[5] Nevertheless, for what it is worth, when the 14.5-month-old females were excluded from the overall analysis, a significant effect of Test Type was found, $F(1, 31) = 5.06$, $p = 0.03$ ($\eta_p^2 = 0.14$), suggesting goal path categorization. There was no main effect of age nor was there a significant interaction between age and test type (*ps* > 0.10). Thus, when familiarized to events including goal paths and tested on highly similar events (events that have the same figure, motion, and reference object) that include a different goal path vs. a novel source path, most infants categorized the goal path.

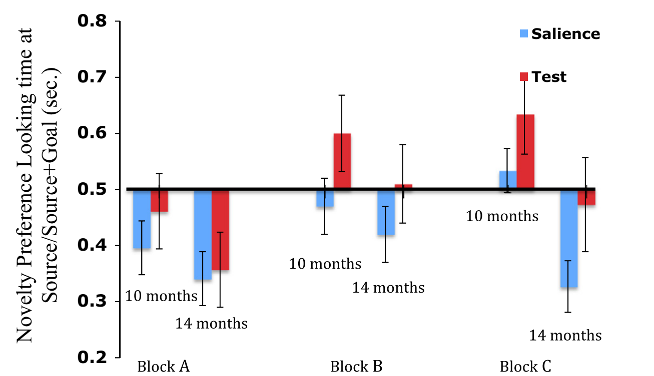

Fig. 6. Average looking time differences (and *SE*s) at the source path vs. goal path events (and *SE*s) for the two different trial types (salience, test). Data are presented for 10- and 14.5-month-olds for the three blocks (A – novel spatial relation only, B – novel spatial relation and novel reference object, and C – novel spatial relation, reference object, and figure).[6]

4.2.2.2. Block B: novel spatial relation (containment), novel reference object compared to familiarization

Out of the 30 10- and 14.5-month-olds who participated in this study, 26 10-month-olds (13 male) and 24 14.5-month-olds (13 male) participated in Block B. The remaining infants were excluded because of fussiness and one 10-month-old looked away for the first two seconds of the test trials.

A 4 (Familiarization trial: 1–4) × 2 (Age: 10, 14.5) ANOVA yielded no significant interaction or main effects (*ps* > 0.10). Although the pattern of the means reveals that infants' looking duration of the events declined over the course of familiarization (Table 5), the differences among the trials were not significant.

For Block B, both 10- and 14.5-month-olds looked longer at the source path events during test versus the salience trial (Fig. 6). A 2 (Trial Type: Salience, Test) × 2 (Age: 10, 14.5) ANOVA yielded a significant main effect of trial type, $F(1, 48) = 4.46$, $p = 0.04$, $\eta_p^2 = 0.09$. The main effect of age and the interaction between age and trial

[5] It may be of interest to note that no other main effects or interactions were significant with the exception of the two-way interaction between familiarization trial and sex, $F(1, 38) = 11.59$, $p = 0.002$. Whereas both 10- and 14.5-month-old males' looking times decreased from the first to the second half of familiarization (*Ms.* = 16.76 vs. 14.71 for 10 months and 19.27 vs. 15.50 for 14.5 months) both the 10- and 14.5-month-old females' showed the opposite pattern (*Ms.* = 12.42 vs. 14.72 for 10 months and 16.44 vs. 16.87 for 14.5 months). Thus, although it's possible that 14.5-month-old females' apparent lack of familiarization followed by longer looking at the goal path events during test (compared to salience) may suggest a familiarity effect, the 10-month-old females did not show this pattern. This contrasting result for the 14.5 month-old females was not predicted and was not found for any of the analyses for Blocks B and C. Further, no other significant interactions with sex were found for the familiarization data for Blocks B and C. Thus, we leave it as a question for future research of whether male and female infants may differ in their abilities to categorize spatial relations. To our knowledge, other than a sex difference during habituation observed by Casasola (2005b), sex differences have not been reported in this particular domain.

[6] Examination of looking times during the salience phase (see Fig. 6) reveals that 14.5-month-olds show a clear goal path bias; they look longer at goal paths than source paths as has been found in several other studies by Lakusta and colleagues. However, 10-month-olds seem to show less of a goal path bias across blocks, raising the question of whether such as bias may differ for younger infants. To our knowledge, goal vs. source encoding has only been tested in 12-month-old infants and older.

type were not significant ($Fs < 0.96$, $ps > 0.33$) (Fig. 6). Thus, when the test events have a different reference object compared to the familiarization events, infants of both ages showed evidence for goal path categorization. None of the counterbalanced variables (sex, block order, and side of goal /source reference objects) significantly interacted with the variable of interest (Trial Type; $ps > 0.10$).

4.2.2.3. Block C: novel spatial relation (containment), novel reference object, novel figure, compared to familiarization

Out of the 30 10- and 14.5-month-olds who participated in this study, 26 10-month-olds (14 male) and 19 14.5-month-olds (10 male) participated in Block C. Four 10-month-olds and seven 14.5-month-old infants were excluded because of fussiness. Further, data from one 14.5-month-old was excluded because his mean looking time at the test trials fell outside 2 SD above the mean; data from three 14.5-month-olds were excluded because they looked away from the screen for the first 2 s of the test videos.

A 4 (Familiarization trial: 1–4) × 2 (Age: 10, 14.5) ANOVA yielded a significant main effect of familiarization trial, $F(3, 129) = 3.18$, $p = 0.03$, $\eta_p^2 = 0.07$; this main effect was subsumed by a marginally significant interaction between familiarization trial and age, $F(3, 129) = 2.37$, $p = 0.07$, $\eta_p^2 = 0.05$. As shown in Table 5, 14.5-month-olds showed an increase in looking time on the fourth familiarization trial, whereas 10-month-olds did not. There was a marginally significant main effect of age, $F(1, 43) = 4.15$, $p = 0.05$; on average, 14.5-month-olds looked longer overall than 10-month-olds.

Despite these slightly different patterns of looking at the familiarization events, both 10- and 14.5-month-olds categorized the goal paths; they looked longer at the source vs. goal path events at test compared to the salience trial (see Fig. 6). A 2 (Trial Type: Salience, Test) × 2 (Age: 10, 14.5) yielded a significant main effect of trial type, $F(1, 43) = 4.24$, $p = 0.045$, $\eta_p^2 = 0.09$. There was also a significant main effect of age $F(1, 43) = 7.88$, $p = 0.007$ $\eta_p^2 = 0.155$, reflecting that, collapsed over salience and test, 14.5-month-olds looked less at the source path events than the goal path events compared to the 10-month-olds. The interaction between age and trial type was not significant, $F = 0.15$, $p = 0.70$. Thus, when the test events have a different reference object and figure compared to the familiarization events, infants show evidence for goal path categorization. None of the counterbalanced variables significantly interacted with the main variable of interest, trial type.

In sum, the results of Experiment 3 provide a conceptual replication of the goal path categorization results of Experiment 1 with 14.5-month-olds (really, three different replications – one for each Block). They also extend the finding of goal path categorization to younger, 10-month-olds infants. The implications of these findings are discussed below.

5. General discussion

As discussed in the Introduction, the semantic roles of goal and source in language are broad and abstract (Jackendoff, 1983). The current study is the first investigation (to our knowledge) that tests whether infants' representations of endpoints and starting points in motion events are also broad and abstract. We asked, do infants conceptualize endpoints and starting points not only in terms of specific spatial relationships, such as containment and support (Casasola, 2008), but also as more general concepts of GOAL PATH and SOURCE PATH - ones that may map to the broad semantic roles in language? The findings from the current study suggest that they do and, moreover suggest that such concepts may exist prior to acquisition of the relevant language.

In Experiments 1 and 3, 14.5-month-old infants showed evidence of goal path categorization. In Exp. 2, when the reference objects were larger in size and more colorful than they were in Exp. 1, 14.5-month-olds also showed evidence for source path categorization. Lastly, in Exp. 3, using a different methodology to test categorization, 10-month-old infants, and a new group of 14.5-month-old infants, showed evidence for goal path categorization. Further, these very same infants (especially the 10-month-olds) were reported to not yet comprehend, "to", "into", and "onto" - the spatial language in English frequently used to encode goal paths. The presence of a general goal concept in pre-verbal 10-month-olds suggests that the general concept of GOAL PATH precedes the acquisition of the corresponding semantic structure, raising the possibility that this general concept may bootstrap acquisition of the relevant language. These findings not only support our understanding of the mechanisms involved in mapping pre-verbal thought into language, but also contribute to research exploring infants' understanding of spatial relations more generally. They also open several doors for future research.

First, considering mechanisms, evidence for a broad concept of GOAL PATH in 10-month-olds lends support for theories positing that infants' representations can 'directly' map into language (e.g., via linking rules; Bloom, 1999; Landau & Gleitman, 1985; Pinker, 1984) and challenges theories arguing that such abstract concepts are constructed from acquisition of the relevant language (Tomasello, 2003). That is, what does *not* seem to be the case from current findings is that children need to comprehend the relevant goal path language (e.g., "run <u>to x</u>", "swim <u>into x</u>", "move <u>onto x</u>") in order for a more general concept of GOAL PATH to emerge. Rather, such a general concept appears to characterize children's conceptual repertoire prior to the relevant language acquisition.

This finding raises several questions for future research. First, is this also the case for other semantic roles, such as source paths, via paths, and agents? In the current study, 14.5-month-olds did not readily categorize the source paths in Exp. 1. Only when the source reference objects were made larger and more colorful was successful categorization observed (Exp. 2). This is consistent with, and extends, previous research reporting that goal paths may be privileged over source paths in pre-verbal thought (Lakusta & Carey, 2015; Lakusta & DiFabrizio, 2016; Lakusta & Landau, 2005, 2012; Lakusta et al., 2007). Given this less prominent role of source paths in pre-verbal thought, perhaps language in this case (e.g., "from", "off", "out", in English) plays a pivotal role in conceptual development, as has been found for other cases where language promotes categorization of objects and spatial relations (e.g., Baldwin & Markman, 1989; Booth & Waxman, 2002; Loewenstein & Gentner, 2005; Namy & Gentner, 2002; Pruden et al., 2013; see Casasola, 2008, for a review). Future research can explore this possibility by perhaps adding source path language ("off the box", "from the tree", etc.) to the familiarization phase of the categorization task in Exp. 1 and/or by testing source path categorization in older infants – infants who are more likely to have acquired the relevant spatial language.

The current findings are highly pertinent to research exploring infants' representations of spatial relations such as support and containment (e.g., Baillargeon, 2004; Casasola, 2005a, 2005b; Casasola & Cohen, 2002; Casasola et al., 2003; Hespos & Baillargeon, 2001). In motion events (vs. static events), support (frequently marked by "on" in English) and containment (frequently marked by "in" in English) are two different types of goal paths – they mark the figure moving to the reference object. Baillargeon's research has shown that infants as young as 6 months of age are able to discriminate containment and support relations (see Baillargeon, 2004 for a review). Casasola and colleagues have reported that infants as young as 6 months can categorize containment relations (Casasola et al.,

2003) and by 14 months infants can categorize support relations under certain task conditions (Casasola, 2005b). The current findings extend this research by showing that not only do infants represent these specific spatial relationships, but they also represent the more general relationship of goal path (moving to an object), as well as source path (moving away from an object) when the starting point objects are sufficiently salient. Whether infants categorize different *specific* types of source paths (out of, off of) is a question left open for future research.

An important question for future research is whether the more general concept of GOAL PATH found in 10- and 14.5-month-olds (current study) precedes the categorization of specific goal paths, such containment ('into') and support ('onto'). Since goal paths (and source paths) are proposed to be universal linguistic structures (Jackendoff, 1983, 1990) then it is quite possible that an abstract, general goal path category precedes categorization of more narrow spatial relationships (which are lexicalized differently across languages; e.g., tightness of fit in Korean vs. support/-containment in English). The finding of goal path categorization in 10-month-olds suggests that this more general concept may precede acquisition of the more narrow concepts, especially the concept of support, which does not seem to be robust until about 14 months (Casasola, 2005b). Studies testing categorization of containment ('in'), support ('on'), and goal path with the same method and stimuli would shed light on this question.

A final related question left open for future research concerns the precise nature of representations of goal and source paths in infants; that is, just *how* abstract are these concepts? The current study took the first step in addressing this question by exploring whether infants can categorize goal paths and source paths in motion events. But, as discussed in the Introduction, the semantic roles of goal path and source path in language are proposed to be highly abstract – extending to events that cross-cut several conceptual domains (e.g., animate and inanimate motion events, change of possession, change of state; Jackendoff, 1990). If infants' representation of goal path and source path supports the mapping into language, then infants should be able to categorize goal and source paths across events that fall into different conceptual domains. That is, they should not only show evidence for goal and source path categorization across different types of motion events, but they should also show evidence for categorization across other classes of events that have goal and source paths, such as change of possession events (girl catches a ball; the girl is a goal/endpoint of the action, as well as a recipient/girl throws a ball; the girl is a source/starting point of the action, as well as an agent) and change of state events (girl's hair turns to red; the goal is an end state/girl's hair turns from red; the source is a starting state). Linguistic analyses (Jackendoff, 1990) suggest that all these events have semantic structures that can select for goal and source paths. Thus, testing the degree of abstractness of infants' representations would be highly pertinent to understanding whether infants' representations of goal and source paths are sufficiently abstract for mapping directly into language. It would also be highly pertinent to theories exploring the representational format of pre-verbal thought (e.g., see Mandler, 2012).

In conclusion, the present experiments tested whether infants are able to categorize goal and source paths in dynamic motion events. Our results suggest that infants categorize goal paths as early as 10 months of age – an age that precedes the acquisition of the relevant spatial terms in English ("to", "on", and "in"). Thus, infants' representations of goal paths may map directly into the semantic structure of goal path in language. Categorization of source paths was less robust, with 14.5-month-olds only showing evidence for categorization when the source paths were sufficiently 'salient', raising the possibility that language may play a role in the acquisition of this concept. Current work in our laboratory is testing the degree of abstractness of goal concepts in infants as well as what role a broad concept of GOAL PATH plays in the acquisition of the relevant spatial language.

Acknowledgements

We gratefully acknowledge the assistance of Rachel Reardon, Leona Oakes, and Jessica Batinjane who helped collect, analyze, and interpret the data in this study and Amrita Bindra who assisted with preparation of this manuscript. We also thank the infants and parents who participated and made this study possible. Finally, we are grateful to Susan Carey for her dedicated mentorship throughout this project as well as for highly insightful comments about this manuscript. This research was supported by NIH grant 5F32HD051197 and NSF grant 1145762 awarded to Laura Lakusta.

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