Developmental Psychology
2014, Vol. 50, No. 7, 1985–1998

0012-1649/14/$12.00 http://dx.doi.org/10.1037/a0036970

Lexical, Syntactic, and Semantic-Geometric Factors in the Acquisition of Motion Predicates

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We report a study that explored the mechanisms used in hypothesizing meanings for novel motion predicates (verbs and prepositions) cross-linguistically. Motion stimuli were presented to English- and Greek-speaking adults and preschoolers accompanied by (a) a novel intransitive verb, (b) a novel transitive verb, (c) a novel transitive preposition, or (d) no novel predicate. Our study provides evidence that both language-specific (lexical) and universal (syntactic and semantic-geometric) factors shape the acquisition of motion predicates cross-linguistically. Lexical biases lead to distinct interpretations (more or less manner- vs. path-oriented) for novel intransitive verbs in English and Greek; however, syntactic (transitivity) cues overcome lexical biases and lead to uniformly path interpretations for novel transitive verbs in both languages. Syntactic (transitivity) cues also lead to path interpretations of novel motion prepositions. Finally, semantic-geometric constraints lead learners in both languages to assume that path interpretations abstract away from visual details of the motion path.

Keywords: path, manner, verb learning, motion, spatial language

Spatial language is known to emerge quite rapidly in young children, and spatial vocabulary seems to be mapped onto prelinguistic space and motion concepts (Baillargeon, 1986, 1987; Bowerman, 1978, 1980, 1996; Casasola, 2008; Clark, 2004; Gibson & Spelke, 1983; Hespos & Spelke, 2004; Johnston, 1984, 1985; Kellman, 1995; Landau, 1994; Piaget & Inhelder, 1956; Pruden, Göksun, Roseberry, Hirsh-Pasek, & Golinkoff, 2013; Pulverman, Golinkoff, Hirsh-Pasek, & Sootsman Buresh, 2008; Quinn, 1994). These findings, together with the fact that spatial language is constrained by our cognition and the physical geometry of our environment, have led to the expectation that languages around the world would structure spatial semantics in a similar way. However, recent work has shown that significant cross-linguistic differences exist alongside cross-linguistic similarities in spatial semantics; furthermore, this variation impacts the early acquisition of spatial vocabulary (Bowerman & Choi, 2001; Brown, 1994; Choi & Bowerman, 1991; Levinson, 1994, 1996; MacLaury, 1989; Talmy, 1985).

This article was published Online First May 26, 2014.

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This research was funded by Grant 1R01HD055498 from the Eunice Kennedy Shriver National Institute of Child Health and Human Development to Anna Papafragou. We would like to thank the Early Learning Center in Newark (Delaware) and all other preschools in the United States and Greece that participated in the study and the University of Ioannina undergraduate students who volunteered to participate. We also acknowledge Angeliki Athanasopoulou, Carol-Ann Edie, and Jennifer Silver for their help in collecting and coding the data, as well as Roberta Golinkoff and Gabriella Hermon for their useful comments.

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In this article, we ask how adults and children from different language communities acquire novel motion predicates (both verbs and prepositions). More specifically, we explore how lexical, syntactic, and semantic-geometric factors interact to constrain the generalization of novel motion predicates across different languages in both language-specific and language-general ways.

Acquiring Novel Motion Predicates

Languages analyze motion as the displacement of an object (figure) with respect to a second, reference object (ground; Talmy, 1975). Additionally, languages may specify the path of motion, that is, the trajectory of the figure object with respect to the ground, as well as the manner of motion, that is, the rhythm, motor pattern, and rate of motion (Jackendoff, 1990; Slobin, 2004; Talmy, 1975, 1985, 1991, 2000). In the English sentence in (1) below, *the man* is the figure, *the cave* is the ground, *swam* indicates the manner of motion, and *into the cave* encodes the path or direction of the motion event:

(1) The man swam into the cave.

Even though languages broadly encode these motion components, there are also fairly large cross-linguistic differences in how path and manner are encoded (Beavers, Levin, & Tham, 2010; Slobin, 1996, 2003; Talmy, 1985, 2000). For instance, satellite-framed (S-framed) languages such as English, Russian, and Hebrew encode manner of motion in the main verb (cf. English *run, swim*) and use a path satellite such as a particle or prepositional phrase to encode path information (*away, to the station*).[1] Verb-framed (V-framed) languages such as Greek, French, Spanish and

[1] We adopt Beavers et al.'s (2010) modified notion of a satellite, as opposed to Talmy's original definition. For a refinement of the typological patterns reported here, see Beavers et al.

Turkish often encode path of motion in the main verb (e.g., Greek *vjeno* [*exit*], *diashizo* [*cross*]) and use additional path and manner modifiers to elaborate on aspects of the motion event (e.g., Greek *sto spiti* [*to the house*], *trehontas* [*running*], respectively).[2] Overall, frequency of use of manner verbs is higher in the first compared to the second group of languages. Thus, the Greek equivalent to the sentence in (1) is (2):

(2) *O andras bike sti spilia kolibontas.*

The man entered into-the cave swimming.

Several studies on English, French, Greek, Spanish, and Turkish, among others, have confirmed that these language-specific verb encoding preferences are present in the speech of both adults and children as young as age 3 (Allen et al., 2007; Berman & Slobin, 1994; Hickmann, 2006; Naigles, Eisenberg, Kako, Highter, & McGraw, 1998; Özçaliskan & Slobin, 1999; Papafragou, Hulbert, & Trueswell, 2008; Papafragou, Massey, & Gleitman, 2002, 2006; Slobin, 1996, 2003).

These language-specific lexical preferences for encoding motion information have implications for the way learners interpret newly introduced motion verbs: Adult speakers of S-framed languages such as English are more likely to prefer manner interpretations of novel motion verbs in intransitive/neutral frames compared to speakers of V-framed languages such as Spanish or Greek (see Maguire et al., 2010; Papafragou & Selimis, 2010b; see also Naigles & Terrazas, 1998). Lexicalization biases also have been claimed to affect children's conjectures about the meaning of newly encountered verbs. Maguire and colleagues (2010) reported that 2-year-olds adopt similar (mostly path-oriented) motion verb construals across languages but that by age 3, children start to diverge in their preferences. Other studies have confirmed differences in the distribution of manner- and path-oriented interpretations of novel verbs in older children acquiring S- and V-framed languages (Papafragou & Selimis, 2010b; cf. Hohenstein, Naigles, & Eisenberg, 2004).

Language-specific lexical preferences interact with structural factors in shaping the interpretation of novel predicates. In one study, both English- and Spanish-speaking adults tended to adopt more path-based interpretations of novel motion verbs when the verbs appeared in a transitive frame (*She is kradding the tree*) compared to an intransitive frame (*She is kradding toward the tree*; Naigles & Terrazas, 1998)—most likely because the transitive frame, unlike the intransitive one, encouraged a relational/path interpretation of the predicate. However, transitivity led to more reliable path conjectures in Spanish, where the transitive syntactic frame was consistent with the language-specific (path-oriented) verb lexicalization biases; in English, where the transitive frame contradicted the (manner-oriented) language-specific verb biases, participants were ambivalent between manner- and path-based verb generalizations. Under the same paradigm, both English- and Spanish-speaking 3-year-olds have been found to extend novel motion verbs in transitive frames on the basis of sameness of path (Hohenstein et al., 2004; see Papafragou & Selimis, 2010b, for a related result).

These studies suggest a role for both lexical/language-specific and syntactic/language-general factors in the interpretation of novel motion verbs. However, the potency and scope of these factors are by no means settled. For instance, previous studies have consistently used forced-choice tasks to investigate lexicalization biases and their interaction with syntax (Hohenstein et al., 2004; Maguire et al., 2010; Naigles & Terrazas, 1998; Papafragou & Selimis, 2010b). Typically, in these studies, participants were shown videos showing an agent performing a motion that featured both a path and a manner component (e.g., a woman skipping toward a tree; Hohenstein et al., 2004; Naigles & Terrazas, 1998). Participants heard a description of the event featuring a novel verb. Later, participants were presented with two novel motion events preserving either the path or the manner of the original event and were asked to "find Ving." The rationale behind this design was that if participants interpreted the verb as a path verb, they should choose the same-path alternative and that if they interpreted the verb as a manner verb, they should choose the same-manner option. By clearly isolating and contrasting the meaning parameters of manner and path, previous work simplified the learning problem children face in deciding how to interpret a newly heard motion verb: These studies showed no evidence that an actual verb interpretation bias exists in spontaneous (not forced-choice) extensions of verb meanings or how potent such a bias might be after encountering a novel motion verb in situations that more closely resemble the actual circumstances of verb acquisition.

An additional complication is that much prior work did not include systematic nonlinguistic controls of the motion events used in verb learning contexts (see Papafragou & Selimis, 2010b, for an exception). In the absence of such controls, it is hard to establish how linguistic factors might shift underlying nonlinguistic preferences for processing motion. Furthermore, it remains possible that differences across studies and populations in the interpretation of novel ambiguous motion verbs might be due to differences in the nonlinguistic salience of manner versus path in the stimuli.

Beyond these methodological points, the broader empirical and theoretical picture of the cross-linguistic acquisition of motion terms remains limited in several ways. First, many of the studies cited above have documented a consistent manner bias in the way speakers of English, an S-framed language, interpret novel ambiguous motion verbs (Hohenstein et al., 2004; Maguire et al., 2010; Naigles & Terrazas, 1998; Papafragou & Selimis, 2010b); furthermore, this lexical bias has been reliably observed in several age groups, including 3- and 5-year-olds as well as adults. However, to date, there is limited evidence of a corresponding strong path bias in a V-framed language. Such evidence comes primarily from 5-year-old and adult speakers of Greek (see Papafragou & Selimis, 2010b). Evidence from Spanish, another V-framed language, is mixed: In one study, Spanish-speaking 3- and 5-year-olds as well as adults appeared neutral between manner and path interpretations for novel motion verbs (Maguire et al., 2010); in another study, the path bias seemed to emerge in Spanish-speaking 7-year-olds but not younger children (Hohenstein et al., 2004). These differences between members of the V-framed language group could potentially be attributed to subtle differences in the distribution of path verbs, with languages such as Spanish being more balanced in their

[2] Other languages such as Japanese appear to be mixed systems. We do not discuss such systems here (but see Maguire et al., 2010).

motion verb inventories and/or usage compared to languages such as Greek. Alternatively, it could be that these differences are due to variations in the stimuli or instructions across studies (for discussion of these possibilities, see Maguire et al., 2010; Papafragou & Selimis, 2010b). Be that as it may, at present, we do not know how early learners of a language with a large and varied *path* verb lexicon can build generalizations about the meaning of novel verbs compared to speakers of a language with a large and varied *manner* verb lexicon. In the absence of such evidence, claims about the early impact of lexicalization biases on cross-linguistic verb acquisition remain tentative.

Second, motion predicates extend beyond verbs to include prepositions. Motion prepositions encode relational (path) content across languages (Beavers et al., 2010; Slobin, 1996, 2003; Talmy, 1985, 2000). We know that transitive syntax is a reliable cue to relational (locative) interpretations of spatial terms referring to static configurations: When they hear a sentence such as *This is acorp my box*, 3- and 5-year-olds are likely to interpret *acorp* as a spatial preposition referring to the position of the figure in relation to the ground; by contrast, when they hear *This is a corp*, children are much more likely to interpret the stimulus as a novel noun identifying the figure object (Landau & Stecker, 1990). These effects emerge as early as age 2 (Fisher, Klingler, & Song, 2006). It is an open question whether syntax can also lead children to hypothesize relational/path (as opposed to manner) meanings for novel prepositions in dynamic (motion) events (*This is going acorp the box*). It is also an open question whether there might be cross-linguistic differences in adopting such path conjectures. For instance, recall that in S-framed languages (e.g., English), prepositions bear the burden of expressing path information, while, in V-framed languages (e.g., Greek), prepositions share this burden with motion verbs. One possibility is that, for both types of language, transitive syntax prompts path interpretations for novel motion prepositions. An alternative or additional possibility is that, in V- but not S-framed languages, the assignment of a path interpretation to a novel preposition is mediated by the type of information encoded in the main verb.

A final limitation of current work is that several other factors beyond the lexical and syntactic constraints explored above exert pressure on how a novel motion predicate (verb or preposition) is interpreted. Nevertheless, such factors have not been examined systematically in the literature. For instance, one of the universal design features of language is that it requires little or no information about individual objects or specific trajectories in order to convey how these objects move (Landau & Jackendoff, 1993; Talmy, 1985, 2000). Cross-linguistic systems of motion typically represent figures and grounds as points, areas, surfaces, or volumes, at most preserving quite restricted geometric properties such as axial structure (Talmy, 1985, 2000). Most relevantly for present purposes, across languages, the relation between figure and ground in motion paths is represented in broad geometric terms such as intersection, containment, enclosure, and contact, without attention to the figure's precise position with respect to the ground or metric distance between the two. For example, to say that A goes into/enters B requires little information about the precise configuration of A and B or the specifics of the motion path. In that sense, the linguistic encoding of motion is much coarser and sparser than the visual information about the motion of objects that humans retain and use in different spatial tasks (e.g., judgments of spatial similarity or navigation in space). At present, it is unknown whether this semantic-geometric constraint is observed by young children acquiring motion vocabulary in their language and how this universal bias might interact with other biases shaping the acquisition of motion predicates.

Present Study

The present study examined how lexical, syntactic, and semantic-geometric constraints are used by adults and young children speaking different languages in hypothesizing meanings for motion predicates (verbs and prepositions). Specifically, the study compared construals of ambiguous motion predicates in 3-year-old, 5-year-old, and adult speakers of an S-framed language (English) and a V-framed language (Greek). The present experimentation expanded both the empirical and theoretical coverage of the cross-linguistic acquisition of motion predicates in the literature (examining the potency of lexicalization biases, especially in V-framed languages; including prepositions as well as verbs; and adding semantic-geometric constraints to the more widely studied lexical and syntactic constraints). The goal was to provide a more complete and nuanced picture of how motion language is acquired cross-linguistically.

The basic design of the study was as follows. Participants viewed a *sample* motion event in which an agent followed a specific path (*through* a ground object) moving in a specific manner (*flipping*). We chose *through* as the path because our prior work indicated that the corresponding expressions (English *through*, Greek *pernao* [*pass*] and *mesa apo* [*through*, literally *inside from*]) are not reliably produced even by 4- to 5-year-olds (Johanson, Selimis, & Papafragou, 2014; see also Grimm, 1975; Johnston & Slobin, 1979, for further cross-linguistic evidence). Similarly, we chose *flipping* as the manner because it was unlikely to be correctly lexicalized by our young participants.

As they viewed the sample event, participants heard a sentence describing what the agent did with a novel intransitive verb (*X is acorping*/*I X feni*), a novel transitive verb (*X is acorping the Y*/*I X feni to X*), a novel preposition (*X is going acorp the Y*/*I X pai fena apo to Y*), or no novel predicate (*X is doing something*/*I X kani kati*). Next, participants viewed a series of *target* events in which a new agent moved in a way that replicated the path of the sample event, the manner, both the path and the manner, or neither. Of interest was whether and how participants would extend the novel predicate to the target events (when there was no novel predicate, participants were asked if the agent in each target event did "the same").

Our study included two methodological differences from previous studies. First, rather than a forced-choice task where participants were required to pick either path or manner in extending the meaning of a new predicate, we used an open-ended task that allowed multiple possible approaches to predicate learning. For instance, participants could accept as an instantiation of the novel predicate only an exact replication of the original event (where both path and manner elements were maintained); alternatively, participants could extend the novel predicate along a single dimension (either path or manner); finally, participants might fail to generalize consistently at all. Second, unlike much prior work, we

introduced a no-predicate condition to test whether the potential biases observed in novel predicate acquisition would be maintained in the absence of language.

To examine the role of language-specific lexical pressures on how speakers interpret novel ambiguous motion verbs, we looked at the intransitive verb condition. The frame used in that condition was neutral with respect to manner- versus path-oriented responses (Papafragou & Selimis, 2010b). To the extent that lexical biases affect verb construals, English speakers of all ages should tend toward manner interpretations and Greek speakers should tend toward path interpretations for newly encountered intransitive motion verbs. We were particularly interested in seeing whether this would hold for 3-year-old learners (especially with respect to the path bias) or whether 3-year-olds might diverge from older learners and adults in terms of their verb conjectures.

To examine the role of language-general structural cues on the interpretation of novel motion terms, we inspected the transitive verb and preposition conditions. In both conditions, transitive syntax should guide both English and Greek speakers toward path interpretations of the novel predicate. No difference was expected between adult speakers and children in either language. The effects of transitivity were expected to be particularly striking in the case of English speakers acquiring novel verbs, since, in that group, effects of syntax would overcome any language-specific lexicalization biases expected to emerge in the intransitive verb condition.

To ensure that the observed effects in the previous three conditions were due to linguistic stimuli as opposed to nonlinguistic factors, we examined the no-predicate condition. We expected that the path and manner components in our stimuli would be of equal salience, such that the no-predicate condition (unlike previous conditions) would reveal no particular preference for either path-based or manner-based responses in any language or age group.

Finally, to investigate the role of universal, semantic-geometric factors in the acquisition of both verbs and prepositions, we focused on the path component of motion (the trajectory through the barrel in our sample event). Semantically, English *through* specifies motion "along a line that is located within a medium" (Talmy, 2000, Vol. 1, p. 164). This semantic content carries no information about the particular shape, contour of orientation of the linear path, or precise location of the line within the medium. The same is true of the corresponding Greek expressions *pernao* (*pass*) and *mesa apo* (*through,* literally *inside from*). To test whether young learners are sensitive to this semantic-geometric bias for verbs and prepositions encoding *through* paths, we included a number of "reverse path" trials in all conditions. These trials preserved the manner and path of the original but reversed the directionality of the path from leftward to rightward. We know that changes in directionality of a path are noticed already in infancy (Golinkoff, 1975). Of interest was whether learners would ignore these changes in the superficial form of the motion trajectory when adopting path (*through*) meanings for novel verbs and prepositions. Also of interest was whether there might be developmental effects on the role of directionality, with younger learners more likely to adopt more conservative, directionality-preserving extensions compared to older learners and adults.

Method

Participants

Participants were 120 native English speakers and 120 native Greek speakers. They fell into three age groups, 3-year-olds, 5-year-olds, and adults, with 40 participants in each Age × Language combination.

In the group of English participants, the 3-year-olds were between the ages of 2;6 and 3;9, with a mean age of 3;2 (SD = 0;4), and the 5-year-olds were between the ages of 4;6 and 5;6, with a mean age of 5;0 (SD = 0;4). An additional group of fourteen 3-year-olds and one 5-year-old was excluded due to failure to cooperate (n = 3), *yes*/*no* bias (n = 5), experimenter error (n = 2), failure to follow the instructions (n = 3), or failure to complete the experiment (n = 2).[3] The children were recruited from daycare centers in Newark, Delaware. The English-speaking adults were undergraduate students recruited from the University of Delaware and received course credit for their participation.

In the group of Greek speakers, the 3-year-olds were between the ages of 2;4 and 3;8, with a mean age of 3;3 (SD = 0;4), and the 5-year-olds were between the ages of 4;0 and 5;6, with a mean age of 4;9 (SD = 0;5). An additional group of twenty-six 3-year-olds and twenty-three 5-year-olds was excluded due to failure to cooperate (n = 8), *yes*/*no* bias (n = 19), experimenter error (n = 6), failure to follow the instructions (n = 7), or failure to complete the experiment (n = 9). The relatively high attrition rate might be due to the fact that the Greek-speaking children in our sample may have been less familiar with structured question–answer activities (e.g., because of shorter class schedules, different curricula, or cultural factors) compared to the English-speaking group. The children were recruited from daycare centers in Ioannina, Greece. The Greek-speaking adults were college students recruited from the University of Ioannina and volunteered to participate. All Greek data were collected in Greece by the first author and a research assistant, both native Greek speakers.

Materials

Our stimuli consisted of a series of 12 pairs of animated clips depicting cartoon fish performing simple motion events. The first clip of each pair (*sample*) was always the same: a larger fish (Teacher Fish) always flipped once while moving through a barrel from right to left, across the screen. Little student fish that differed from the teacher only in size and color were watching. In the second clip of each pair (*target*), a student fish tried to imitate the teacher with varying degrees of success. Across targets, the movements of the student fish crossed one of three manners of motion (flipping, bobbing, or dancing[4]) with one of three trajectories (through, over, and under) to give us nine basic target trials (see Table 1).

[3] A *yes*/*no* bias occurred when children provided a single response type (either *yes* or *no*) in all experimental trials. Failure to follow instructions occurred when children engaged in discussion of unrelated topics or described irrelevant aspects of the stimuli instead of answering the test question.

[4] For the *dancing* manner of movement, the fish stood on its tail and rocked back and forth on its vertical axis.

Table 1
List of Trials by Manner/Path Changes

	Paths			
Manners	Through	Over	Under	R(everse) through
Flipping	+manner+path	+manner−path	+manner−path	+manner+path
Bobbing	−manner+path	−manner−path	−manner−path	−manner+path
Dancing	−manner+path	−manner−path	−manner−path	−manner+path

Note. The plus sign shows which component, if any, of the sample event was preserved; the minus sign shows which component, if any, was changed. *R(everse) through* trials reversed directionality from their *through* counterparts.

An additional three target trials crossed the three different manners of motion mentioned above with a new path that went through the barrel but with a reverse (rightward instead of leftward) directionality. We refer to this last group of three trials as the *R*(everse)-*through* trials.

The materials were put together and presented using MS PowerPoint 2007 and a laptop IBM compatible computer (see Figure 1 for examples). Materials were arranged in 10 randomized lists, one for each participant per experimental condition.

Procedure

Participants were randomly assigned to one of four conditions: (a) *intransitive verb*, (b) *transitive verb*, (c) *preposition*, or (d) *no-predicate* ($n = 10$ per condition). All participants saw an introductory screen depicting an ocean scene with a large fish (Teacher Fish) and many smaller, fish (student fish). They then heard the following script: "Teacher Fish is taking her class to play in the ocean. She wants to show her students new fish-tricks today. After swimming in the seaweed for a while she finds a nice barrel!" Participants were next shown the series of 12 pairs of animated clips.

In the intransitive verb condition, after the introductory text, the experimenter said, "I am going to describe what Teacher Fish is doing in fish language, which is the same as English (Greek) apart from a few words . . . ." This step was taken to ensure that participants would not hesitate to assume existing lexical meanings in their language as possible interpretations for the novel words. Participants were next shown the series of 12 pairs of animated clips. During the sample, participants heard "Look! Teacher Fish is acorping!" During each target, they heard "Is the little fish acorping, or not?" The prompts for both the sample and the target were heard once for each sample and each target. The novel verbs for both languages were phonotactically appropriate bisyllabic roots that could easily accommodate both derivational suffixes and inflection. The Greek equivalents of the test sentences follow below:

(3) a. *Kita! I Daskala Psari feni!*

Look! (The) Teacher Fish is acorping!

b. *To mikro psaraki feni, i oxi?*

(The) little fish is acorping, or not?

In the transitive verb condition, the procedure was the same but during the sample of each pair, participants heard "Look! Teacher Fish is acorping the barrel!" During the target, they heard "Is the little fish acorping the barrel, or not?" The Greek equivalents of these test sentences follow below:[5]

(4) a. *Kita! I Daskala Psari feni to vareli!*

Look! (The) Teacher Fish is acorping the barrel!

b. *To mikro psaraki feni to vareli, i oxi?*

(The) little fish is acorping the barrel, or not?

In the preposition condition, the procedure was also the same, but as the sample of each pair played, participants heard "Look! Teacher Fish is going acorp the barrel!" As the target played, they heard "Is the little fish going acorp the barrel, or not?" The Greek equivalents with the corresponding glosses are given below:

(5) a. *Kita! I Daskala Psari pai fena apo to vareli!*

Look! (The) Teacher Fish is going acorp (from) the barrel!

b. *To mikro psaraki pai fena apo to vareli, i oxi?*

(The) little fish is going acorp (from) the barrel, or not?[6]

In the no-predicate condition, as participants watched the sample in each pair, the experimenter said, "Look! Look what Teacher Fish is doing!" As they watched the target, the experimenter asked, "Is the little fish doing the same, or not?" The Greek equivalents of these sentences were as follows:

(6) a. *Kita! Kita ti kani I Daskala Psari!*

Look! Look what is doing (the) Teacher Fish!

b. *To mikro psaraki kani to idio, i oxi?*

[5] Transitive verb frames in some prior studies (Hohenstein et al., 2004; Naigles & Terrazas, 1998) included a transitive verb with a ground object in English (*She's kradding the tree*) but an intransitive verb with a content-poor preposition in Spanish (*Ella está mecando al árbol*). Here, we ensure that the transitive verb frames are exactly parallel across languages.

[6] In our example, the novel preposition *fena* requires the preposition *apo* to form a complex preposition (Terzi & Tsakali, 2009), similar to the complex preposition *off of* in English. In this respect, the novel preposition follows the syntax of canonical complex prepositions in Greek such as *pano apo* noun phrase (NP) = *over* NP, *kato apo* NP = *under* NP, *mesa apo* NP = *through* NP, and so on (for which it is not possible to omit *apo*). The specific spatial meaning in such complex prepositions is primarily contributed by the first preposition.

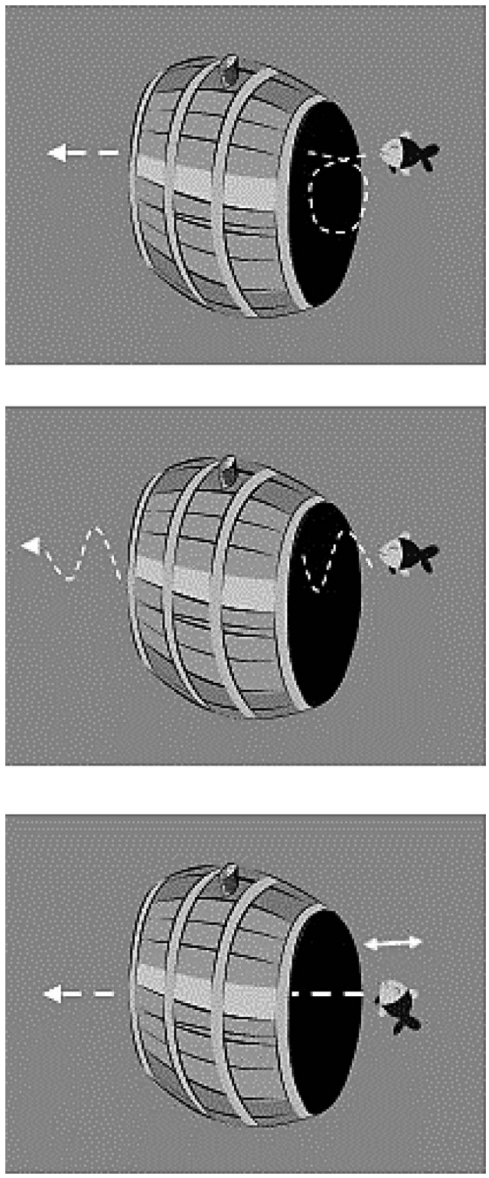

Figure 1. Examples of the three manners (flipping, bobbing, dancing) combined with the *through* path in the stimuli.

(The) little fish is doing the same, or not?

Participants were expected to answer either "yes" or "no" after each of the 12 target trials. The experimenter marked their answer on an answer sheet.

Results and Discussion

Overall, our participants correctly gave "no" responses in target trials ($n = 4$) in which neither the path nor the manner component of the sample event was preserved ($M = .96$) and "yes" responses in the single target trial in which both components were preserved ($M = .97$). This shows convincingly that participants understood the task.

For the target trials in which either path or manner changed from the sample, we calculated a path-bias score as the percentage of "yes" responses in trials in which only the path of the sample was preserved minus the percentage of "yes" responses in trials in which only the manner of the sample was preserved. A score of 1 would indicate an absolute path bias, a score of −1 an absolute manner bias. For simplicity, we did not include R-through trials in these initial analyses (i.e., we limited ourselves to trials in the first three columns of Table 1; for R-through trials, see below).[7]

We conducted an omnibus ANOVA using the path-bias score as the dependent variable and age (3s, 5s, adults), language (English, Greek), and condition (intransitive verb, transitive verb, preposition, no predicate) as factors (see Figure 2). The analysis revealed an effect of age, $F(2, 216) = 10.72$, $p = .00036$, $\eta_p^2 = .09$, with 3-year-olds and 5-year-olds being more path biased than adults ($p = .0001$ and .0015, respectively, two-tailed t test, Bonferroni correction) but no different from each other. The analysis also revealed a marginally significant effect of language, $F(1, 216) = 3.55$, $p = .06$, $\eta_p^2 = .02$; an effect of condition, $F(3, 216) = 9.96$, $p = .00004$, $\eta_p^2 = .12$; and a Language × Condition interaction, $F(3, 216) = 7.44$, $p = .00092$, $\eta_p^2 = .09$; but no other interactions (Language × Age, $p = .944$; Age × Condition, $p = .172$; Language × Age × Condition, $p = .448$).

We further explored the Language × Condition interaction by pairwise comparisons (two-tailed t tests, Bonferroni correction). For Greek speakers, the no-predicate condition elicited lower path-bias scores than each of the other conditions ($p < .05$); there were no other differences between conditions. For English speakers, both the no-predicate and the intransitive verb conditions elicited lower path-bias scores than the other two conditions ($ps < .05$); the no-predicate and intransitive verb conditions did not differ from each other, nor were there any other differences between conditions. Thus, in both languages, the transitive verb and preposition conditions succeeded in increasing path-oriented responses compared to the no-predicate baseline. However, the intransitive verb condition caused a shift toward more path-oriented responses compared to the no-predicate condition only for the Greek speakers—in accordance with the lexical biases of the language. To better understand these results, we conduct more specific ANOVAs within each condition in the sections below.

Before turning to the data within each condition, we looked at individual response patterns across conditions to confirm these conclusions (see Table 2). Response patterns were classified as (a) *path-based,* if participants accepted over 50% of the targets that included only the path component of the sample and rejected all other trials; (b) *manner-based,* if participants accepted over 50% of the targets that included only the manner component of the sample and rejected all other trials; (c) *path+manner-based,* if participants

[7] The decision to leave out R-though trials did not affect the shape of the results. An omnibus analysis of variance (ANOVA) including the R-through trials in the path-bias score returned an effect of age, $F(2, 216) = 4.96$, $p = .008$, $\eta_p^2 = .04$: Three-year-olds and 5-year-olds were more path biased than adults (both $ps = .02$, two-tailed t test, Bonferroni correction) but no different from each other. There was also a marginally significant effect of language, $F(1, 216) = 2.93$, $p = .09$, $\eta_p^2 = .013$; an effect of condition, $F(3, 216) = 7.78$, $p = .000001$, $\eta_p^2 = .13$; and a Language × Condition interaction, $F(3, 216) = 7.44$, $p = .00006$, $\eta_p^2 = .1$. These results are virtually identical to the ANOVA without the reverse trials that is presented next in the main text.

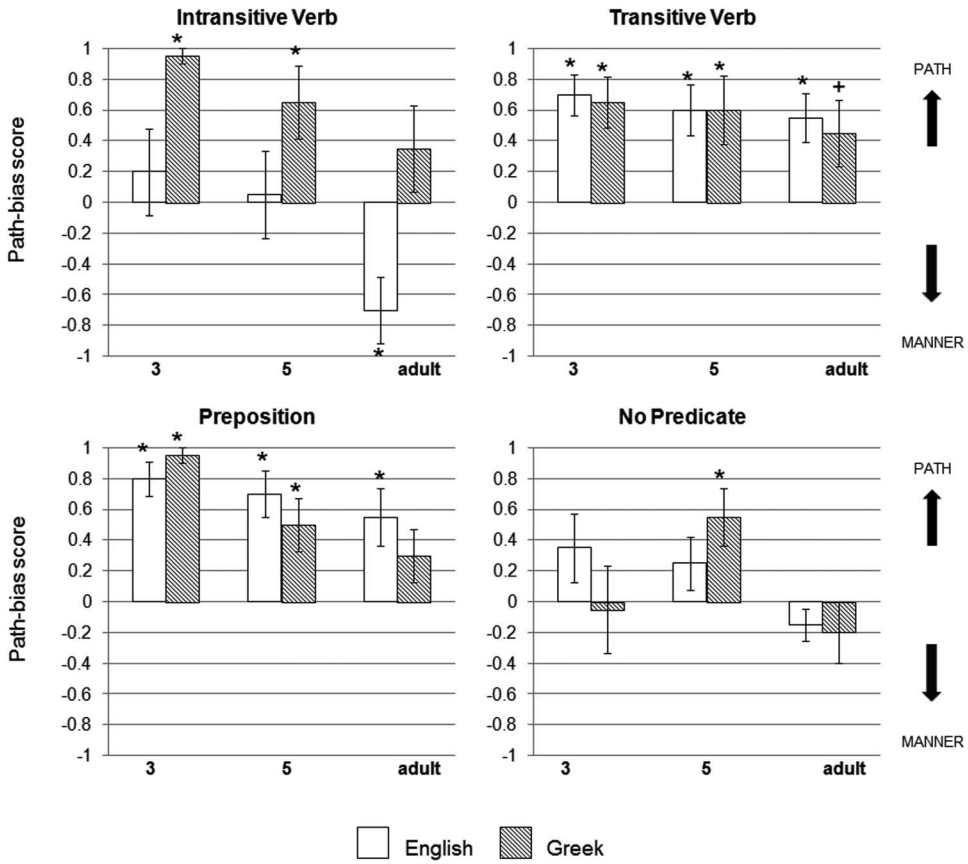

Figure 2. Path-bias score across conditions. Values over 0 indicate path choices, and values below 0 indicate manner choices. Error bars represent standard errors. Symbols indicate comparisons to chance. * Significant at $p < .05$. + Marginally significant at $p = .06$.

accepted only the single target that included both the path and manner components of the sample and rejected all other trials; or (d) *mixed*, if the pattern did not fall into any of the above categories. Each participant was then assigned to a response pattern.

For purposes of the analyses, we distinguished path-based responders from all other participants, since we were interested in how path-based choices might be affected by our experimental manipulations. Collapsing across age groups (due to low numbers), we conducted a separate Fisher's exact test on 2 × 4 contingency tables for each language, asking whether the number of path-oriented responders differed across conditions. The analyses revealed significantly different numbers of path-oriented responders across conditions for both English ($p = .00007$) and Greek ($p = .001$). Pairwise comparisons using the same test on 2 × 2 contingency tables revealed that, for English speakers, the number of path responders increased from the intransitive verb ($n = 8/30$) to the transitive verb ($n = 19/30$) and preposition ($n = 22/30$) conditions ($p = .009$ and .0007, respectively)—presumably because syntax encouraged path interpretations of the novel predicates. The transitive verb and preposition conditions did not differ

Table 2
Generalization Patterns for Each Condition

	Intransitive verb						Transitive verb						Preposition						No predicate					
	English			Greek			English			Greek			English			Greek			English			Greek		
Patterns	3s	5s	Ad	3s	5s	Ad	3s	5s	Ad	3s	5s	Ad	3s	5s	Ad	3s	5s	Ad	3s	5s	Ad	3s	5s	Ad
Path-based	3	4	1	8	8	6	6	7	6	8	8	6	9	5	8	9	5	4	5	3	0	4	6	1
Manner-based	4	4	8	0	2	2	0	0	0	1	1	2	0	0	0	0	0	1	2	1	2	4	1	2
Path + manner-based	2	2	1	0	0	1	0	2	4	1	1	0	0	2	0	0	5	5	2	5	7	1	3	5
Mixed	1	0	0	2	0	1	4	1	0	0	0	2	1	3	2	1	0	0	1	1	1	1	0	2
Total	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10

Note. Cell values reflect number of participants adopting each generalization pattern. 3s = 3-year-olds; 5s = 5-year-olds; Ad = adults.

from each other ($p = .58$). However, for Greek speakers, there was no difference between the number of path responders in the three conditions (intransitive verb: $n = 22/30$, transitive verb: $n = 22/30$, preposition: $n = 18/30$; all ps $> .05$): even when verbs appeared intransitively, high numbers of participants interpreted them as path verbs.

Finally, in the English-speaking group, the number of path responders in the no-predicate condition ($n = 8/30$) was identical to the intransitive verb condition (also $n = 8/30$) but lower than in either the transitive verb ($n = 19/30$) or the preposition ($n = 22/30$) condition ($p = .009$ and .0007, respectively): Transitive but not intransitive frames led English speakers to path-based responses and away from the no-predicate baseline. However, in the Greek-speaking group, the number of path responders increased between the no-predicate ($n = 11/30$) and each of the other three conditions (both intransitive and transitive verbs: $n = 22/30$, $p = .009$; preposition: $n = 18/30$, trend is in the right direction even though nonsignificant at $p = .12$): Both syntax and lexical factors favored path construals in this language compared to the nonlinguistic (no-predicate) baseline.

Intransitive Verb Task

We next looked at the data within each condition more closely. For the intransitive verb condition, we conducted an ANOVA using the path-bias score as the dependent variable and age (3s, 5s, adults) and language (English, Greek) as factors. The analysis returned a main effect of age, $F(2, 54) = 5.21$, $p = .01$, $\eta_p^2 = .16$, with 3-year-olds being more likely to show a path bias than adults ($p < .05$, Bonferroni correction) and no other differences among age groups, and a main effect of language, $F(1, 54) = 16.89$, $p = .0001$, $\eta_p^2 = .24$, with the path bias being significantly stronger in Greek than in English. There was no interaction between age and language ($p = .633$). As expected, the Greek speakers were in general more path-oriented compared to English speakers when hypothesizing the meaning of a novel motion verb appearing in an intransitive frame.

In single-sample t tests comparing individual means to chance ($M = 0$; see Figure 2), English-speaking adults appeared clearly manner biased, whereas Greek-speaking adults tended in the opposite direction but were not path biased at levels significantly different from chance ($p > .05$). Greek-speaking children appeared strongly path biased when their performance was compared to chance ($p < .05$ for both 3s and 5s). By contrast, neither the 3- nor the 5-year-olds in the English-speaking group performed at levels significantly different from chance ($p > .05$).

The overall difference between English and Greek speakers in terms of the likelihood of having a path bias for newly heard intransitive motion verbs is consistent with prior findings on language-specific lexical biases (Maguire et al., 2010; Naigles & Terrazas, 1998; Papafragou & Selimis, 2010b). Our data extend prior work by showing that these tendencies emerge even when participants are free to select meaning components to attend to in the meaning generalization phase (instead of being forced to choose between the manner and path component). Even 3-year-olds, after a single exposure to a novel intransitive motion verb, fast-map the meaning of the verb in accordance with the lexical biases of the language. Our findings also lower the age at which a reliable path lexicalization bias has been found in speakers of a V-framed language such as Greek (compare Hohenstein et al., 2004; Papafragou & Selimis, 2010b).

Despite the fact that Greek learners showed a consistent path bias in our data, no corresponding manner bias characterized the behavior of English learners in our sample. This pattern differs from prior work that showed a clear manner bias for English-speaking preschoolers (e.g., Maguire et al., 2010; Papafragou & Selimis, 2010b). Why did English-speaking children in our study disregard their native language verb typology when building conjectures for new intransitive motion verbs? A first possibility is that the manner bias might require a longer and more nuanced set of manner verbs to serve as its basis compared to the path bias—and thus might take longer to develop and might emerge inconsistently in studies designed to probe its effects. This possibility would be strengthened if it turned out that the motion verb vocabulary of young English speakers was not dominated by manner verbs, as is the case for adults, and so the grounds for a manner bias would be weak. However, this possibility is not supported by production data showing that manner verbs appear early and are used productively in English by both 3-year-olds and 5-year-olds (Bunger, Trueswell, & Papafragou, 2012; Hickmann & Hendriks, 2006; Papafragou & Selimis 2010b; Slobin, 2003).

A second possibility is that the manner component of our sample motion event (*flipping*) might not be a good candidate for a manner verb for young English speakers and/or might be less discriminable as a lexical meaning from the other exemplars of manners we used in the targets (*bobbing* and *dancing*). By contrast, the path in our sample event (*through*) might be a good candidate for a path verb and/or highly discriminable compared to the other paths we used in the targets (*over* and *under*). It is possible that the existing repertoire of manner verbs in English-speaking 3- and 5-year-olds, even though varied, is not fine-grained enough to support fast-mapping of very subtle manner distinctions onto new verbs. Notice that this hypothesis focuses exclusively on the *linguistic* discriminability of our manner versus path exemplars, not their *visual*/*conceptual* discriminability.[8] Support for this hypothesis comes from the fact that prior studies that have documented a manner bias in English-speaking children's verb conjectures used both a varied repertoire of manner exemplars and what appear to be large codability differences between the different exemplars (e.g., doing jumping jacks, twisting, bowing, or spinning; Maguire et al., 2010; see also Papafragou & Selimis, 2010b). At present, we take this second possibility to be the more promising explanation of our English child data.

Transitive Verb Task

We conducted an ANOVA for the transitive verb condition using the path-bias score as the dependent variable and age and language as factors. We found no effects of age ($p = .622$) or language ($p = .734$) and no interaction ($p = .962$). Inspection of Figure 2 reveals that, in this condition, there was a clear overall path bias (all individual means different from chance, ps $< .05$, even though the means for Greek adults marginally so, $p = .06$).

[8] Anticipating results from the no-predicate condition, manner and path exemplars were largely equivalent/equally discriminable when no novel predicate was introduced.

We conclude that the structural cue of transitivity creates a strong bias toward relational or path interpretations for novel motion verbs across languages and age groups. The impact of transitivity overcomes verb lexicalization biases in English-speaking adults and the relative lack of a bias in English-speaking children previously observed in the intransitive verb condition. In this sense, verb transitivity here succeeds in turning English speakers into Greeks. This effect is particularly dramatic in English-speaking children: Despite the fact that they are unlikely to have learned any of the small set of English path verbs (e.g., *enter, exit, approach, traverse*), they are led by the transitive syntax to hypothesize the existence of such verbs in the language.

Finally, these results are consistent with prior studies in which both children and adults have been shown to discover crucial components of a predicate's meaning from syntactic information (Gillette, Gleitman, Gleitman, & Lederer, 1999; Landau & Gleitman, 1985, among many others; see also Naigles, 1990; Yuan & Fisher, 2009, for evidence on the specific effects of transitivity). As our data show, a single exposure to a transitive verb is enough to place constraints on the construal of a scene by children as young as 3 years.

Preposition Task

In the preposition condition, an ANOVA with path bias as the dependent variable and age and language as factors yielded only a main effect of age, $F(2, 54) = 4.7$, $p = .01$, $\eta_p^2 = .15$, with 3-year-olds more likely to show a path bias compared to adults ($p < .05$, Bonferroni correction) but 5-year-olds being similar to adults ($p > .05$). There was no effect of language ($p = .41$) and no interaction between age and language ($p = .343$). As shown in Figure 2, there is a clear path bias overall, with all individual means different from chance ($p < .05$). One exception is the performance of Greek-speaking adults, who trended in the same direction but whose performance was not different from chance, $t(9) = 1.7$, $p = .1$.

Overall, the present data show that, cross-linguistically, the combination of a general path verb with a new predicate combined with a ground object (*going acorp the X*/*pai fena apo to vareli*) leads learners to adopt relational interpretations for the new predicate (i.e., leads them to treat it as a transitive motion path preposition). Furthermore, these interpretations become available even after a single exposure to the novel predicate. This conclusion coheres with the well-known fact that structural cues are available from early on and guide the interpretation of new lexical items for children (Golinkoff & Hirsh-Pasek, 2008; Landau & Gleitman, 1985; Naigles, 1990, 1996; Naigles, Gleitman, & Gleitman, 1993). These data also confirm and extend prior work that demonstrated a role of transitive syntax in the acquisition of static spatial prepositions (cf. Fisher et al., 2006; Landau & Stecker, 1990).

Despite the overall prevalence of path interpretations for novel motion prepositions, the behavior of Greek-speaking adults in the preposition condition appears more mixed than expected. How can this pattern be explained? We propose that this behavior is due to interference from the lexicalization biases of Greek. Recall that, typically, in Greek, motion path information is apportioned between path prepositions and path verbs. For instance, the most preferred way to encode the *through* trajectory in our sample event would be to combine a specific verb such as *pernao* (*pass*) with a preposition such as *mesa apo* (*through*, literally *in from*/*from inside*). Indeed, in a prior study in our lab using scenes similar to the present ones, Greek-speaking adults used this exact verb–preposition combination 63% of the time to describe *through* scenes (3-year-olds only did so 20% of the time and 4-year-olds 33% of the time; Johanson et al., 2014). In the present study, however, rich path information was delegated exclusively to the complex preposition *fena apo* (the general path verb *go* did not contain specific information about the trajectory of the moving object). We believe that this atypical division of semantic labor between preposition and verb led to an unusually high number of Greek-speaking adults adopting a very conservative generalization of the novel predicate, that is, picking the path+manner choice ($n = 5$; see Table 2). For comparison, no Greek-speaking adults picked such conservative generalizations in the transitive verb condition, where transitive syntax was also present but did not conflict with lexical biases (Fisher's exact test, $p = .03$).

Careful inspection of the data reveals that effects of interference between syntax and motion lexicalization biases can also be observed in more subtle ways in English-speaking adults. As Table 2 shows, in the transitive verb condition, where the syntactic frame encouraged assignment of semantic information to a syntactic object in a way that was atypical for English (i.e., path information to a verb instead of a preposition), six people adopted path-based conjectures, but the remaining four people failed to generalize the novel verb and instead adopted path+manner choices (see also Naigles & Terrazas, 1998, for similar effects). By contrast, in the preposition condition, when transitive syntax did not conflict with lexical biases, no English-speaking adults failed to generalize (Fisher's exact test, $p = .08$, a trend in the predicted direction).

No-Predicate Task

For the no-predicate condition, an ANOVA with the path-bias score as the dependent variable and age and language as factors was conducted. There was a main effect of age, $F(2, 54) = 4.04$, $p = .02$, $\eta_p^2 = .13$: Further analyses revealed that 5-year-olds were more likely to show a path bias compared to adults ($p < .05$, Bonferroni correction) but not compared to 3-year-olds ($p > .05$). There was no effect of language ($p = .764$) or interaction of age with language ($p = .235$). Comparisons against chance showed that none of the individual groups seemed to have a path-bias score that was significantly different from chance, with the exception of the Greek-speaking 5-year-olds, $t(9) = 2.9$, $p = .01$ (see Figure 2). It is not clear to us at this point why the Greek-speaking 5-year-olds show such behavior in the no-predicate task (see Papafragou et al., 2002; Papafragou & Selimis, 2010a, for different results).

Taken together, these findings suggest that our stimuli are perceived as largely equibiased between manner and path. These results support earlier findings according to which the categorization and perception of path and manner of motion in nonlinguistic tasks are very similar across various linguistic communities despite cross-linguistic differences in how motion is encoded (Gennari, Sloman, Malt, & Fitch, 2002; Papafragou et al., 2002, 2008; Papafragou & Selimis, 2010a, among others).

The Role of Semantic-Geometric Factors in Path Conjectures

Finally, we examined the role of semantic-geometric factors in participants' interpretation of novel motion predicates. We were interested in whether R-through trials ($n = 3$; see the last column of Table 1) behaved identically to the trials containing the original directional path of the sample ($n = 3$; see the first column of Table 1). In each of these sets of trials, the path was combined either with the original manner ($n = 1$ in each set) or with one of two new manners ($n = 2$). For each condition, we asked whether—to the extent that they made *path-based* choices—participants were more likely to do so when the original (right-to-left) directionality of the path in the sample event was preserved versus reversed. Since specifics of the visual path should be irrelevant for determining the meaning of *through* predicates, participants in conditions that involved predicate learning (intransitive verb, transitive verb, preposition) should ignore directionality changes. However, surface changes in the visual path might be relevant when people were asked to judge the sameness of path in nonlinguistic contexts (no predicate).[9]

In the intransitive verb condition, we decided to conduct separate analyses for the English- and Greek-speaking participants because path-based extensions of the verb in English were very restricted (see Figure 2). For English speakers, we focused on the subset of eight participants across all age groups who consistently came up with path interpretations (see Table 2). A two-tailed paired-samples *t* test comparing the proportion of "yes" responses in the original and reverse path trials revealed no difference, $t(7) = 1.4$, $p = .19$ ($M_O = 1$, $M_R = .88$). Thus, for English speakers, directionality plays no reliable role in determining the extension of a novel intransitive path verb. For Greek speakers, a repeated measures ANOVA with the proportion of "yes" responses as the dependent variable, age (3, 5, adult) as a between-subjects variable, and directionality (original, reverse) as a within-subjects variable returned no effect of age ($p = .121$) or directionality ($p = .271$) and no interaction between age and directionality ($p = .924$). As in English, when adopting path-based extensions of novel intransitive motion verbs, Greek speakers disregarded path directionality ($M_O = .87$, $M_R = .83$).

In the transitive verb and preposition conditions, participants made predominantly path-based responses across languages. For each condition, we therefore ran an ANOVA with age, language, and directionality as factors. In the transitive verb condition, the ANOVA revealed no effects of age ($p = .493$), language ($p = .770$), or directionality ($p = .369$) or any interactions (all ps $> .4$)). Overall, participants ignored directionality when acquiring novel transitive motion verbs ($M_O = .78$, $M_R = .74$). In the preposition condition, a similar ANOVA found no effects of language ($p = .15$) or age ($p = .29$); a marginally significant interaction between language and age, $F(2, 54) = 2.94$, $p = .06$, $\eta_p^2 = .10$; as well as an effect of directionality, $F(1, 54) = 8.71$, $p = .005$, $\eta_p^2 = .14$ ($M_O = .82$, $M_R = .72$), and an interaction between directionality and age, $F(2, 54) = 5.52$, $p = .007$, $\eta_p^2 = .17$: Paired-sample *t* tests showed that 3-year-olds were more likely to accept the original compared to the reverse paths ($M_O = .98$, $M_R = .72$, $p < .05$, two-tailed, Bonferroni correction), while 5-year-olds ($M_O = .77$, $M_R = .70$, $p > .05$) and adults ($M_O = .72$, $M_R = .73$, $p > .05$) showed no such preference. There were no other interactions (all ps $> .17$) Notice that, despite being somewhat more conservative than older learners, even the youngest children accepted reverse paths 73% of the time when learning new spatial prepositions, thereby ignoring visually salient but semantically irrelevant differences between spatial events.

We finally turned to the no-predicate condition. Recall that in this condition, there was no systematic preference for path-based over manner-based responses (with the exception of older Greek-speaking preschoolers; see Figure 2). Therefore, we focused on the subset of participants who consistently chose path-based responses ($n = 19$; see Table 2 for a breakdown). We conducted a paired-sample *t* test using directionality as factor (because of low numbers, this analysis collapsed across languages and ages). The test revealed that participants accepted visually identical paths as being the same more often compared to paths with reverse directions when the task involved no predicate learning, $t(18) = 2.82$, $p = .011$ ($M_O = .95$, $M_R = .67$).

We conclude that when learning novel path verbs or prepositions, children and adults across typologically different languages expect such spatial predicates to follow certain broad semantic-geometric constraints: Specifically, they expect spatial predicates to abstract away from specifics of visual paths such as path directionality and to focus on the geometric relation between the moving (figure) object and the ground object. This conclusion confirms expectations about the abstractness of spatial language in the literature that have not been previously directly tested (Landau & Jackendoff, 1993; Talmy, 1985). A particularly interesting aspect of our results is that sensitivity to path directionality re-emerges in tasks that do not involve language learning: In the no-predicate condition, participants were likely to resist calling directionally reversed paths the same. Thus, the willingness to

[9] We also conducted an omnibus repeated measures ANOVA with the proportion of "yes" responses to the original and reverse path trials as the dependent variable; age, language, and condition as between-subjects variables; and directionality (original, reverse) as a within-subjects variable. The analysis revealed an effect of age, $F(2, 216) = 7.831$, $p = .001$, $\eta_p^2 = .068$, with both 3-year-olds and 5-year-olds being more likely than adults to give a "yes" response to trials that contained either the original or the reverse path ($p = .0004$ and .043, respectively, two-tailed *t* test, Bonferroni correction) but no different from each other. The analysis also revealed an effect of language, $F(1, 216) = 4.243$, $p = .041$, $\eta_p^2 = .019$, with Greek speakers being overall more likely to give a "yes" response than the English speakers; an effect of condition, $F(3, 216) = 13.084$, $p = .0000007$, $\eta_p^2 = .154$; and an effect of directionality, $F(1, 216) = 19.732$, $p = .000014$, $\eta_p^2 = .084$, with participants being overall more likely to respond "yes" to trials that contained the original rather than the reverse directional path ($M_O = .71$, $M_R = .63$). Moreover, the analysis yielded a Language × Condition interaction, $F(3, 216) = 8.122$, $p = .000042$, $\eta_p^2 = .1$, but no other interactions (all ps $> .05$). Pairwise comparisons of Greek and English speakers for each condition (two-tailed *t* tests, Bonferroni correction) showed that Greek speakers were more likely than English speakers to give "yes" responses to trials that contained either the original or the reverse path in the intransitive verb condition ($p < .05$), but no such difference emerged for any of the other conditions (ps $> .05$). As expected, this ANOVA replicated the main results of the previous sections. However, the role of directionality in this analysis is difficult to interpret, since the data include several different ways of construing a novel motion predicate, some of which are in principle more tolerant toward directionality changes than others (cf. Table 2). For our main set of analyses in this section, we therefore took a more nuanced look at the data focusing on path-based conjectures (see the introduction for theoretical motivation).

ignore superficial visual details of paths seems to be tied to the specific context of learning spatial language.

Our data further suggest that, for transitive prepositions, semantic-geometric biases in favor of abstract meanings appear somewhat weaker in younger learners: Recall that 3-year-olds across language groups were more likely to extend the meaning of a novel path (*through*) preposition to path tokens that preserved rather than reversed the directionality of the original motion trajectory. For novel transitive verbs, no such role of directionality was found at any age. Thus younger learners may be more open to adopting specific directional meanings for novel spatial prepositions (*through from left to right* vs. *through from right to left*) compared to novel spatial verbs (*go through from left to right* vs. *go through from right to left*). We hypothesize that the verb–preposition asymmetry results from limitations in young children's experience with spatial prepositions and their relational content, which constrain children's ability to generalize the meaning of previously unheard prepositions as freely as older children and adults.

General Discussion

In the present studies, we set out to examine the cross-linguistic acquisition of motion predicates. Specifically, we looked at how adults and young children use lexical, structural, and semantic-geometric constraints in hypothesizing meanings for novel motion predicates (verbs and prepositions) in two typologically different languages, English and Greek. We were particularly interested in examining whether lexical, structural, and semantic-geometric factors are robust enough to surface when participants are freely extending the meaning of a novel predicate, as opposed to being forced to make a binary choice (Hohenstein et al., 2004; Maguire et al., 2010; Naigles & Terrazas, 1998; Papafragou & Selimis, 2010b). We were also interested in exploring how such factors affect predicate interpretation independently of any extralinguistic constraints.

We focused on the interpretation of motion predicates that were potentially ambiguous between two salient and competing dimensions of dynamic motion events, the path (or trajectory) and the manner (or specific characteristics) of motion. We manipulated whether the same motion term (*acorp* in English, *fena* in Greek) appeared as an intransitive verb, transitive verb, or preposition during the time participants were exposed to an ongoing motion event. The participants' task was to decide whether the novel term could be extended to additional motion events that preserved (a) the manner of the original event, (b) the path of the original event, (c) both the manner and the path of the original, or (d) neither. We also included a condition in which no motion predicate was introduced and participants simply had to choose whether in each additional event the agent was doing the same thing as in the original event.

Together, our experiments point to several key findings. A first major finding is that language-specific motion lexicalization biases affect conjectures for novel motion predicates. Specifically, motion verbs when presented intransitively are interpreted differently by adults speaking typologically different languages: English-speaking adults extend intransitive motion verbs on the basis of sameness of manner, and Greek-speaking adults tend to do so on the basis of sameness of path. Effects of the lexicalization biases emerge early: We found evidence that the path bias is already in place in Greek-speaking 3-year-olds (and persists in 5-year-olds). This is the first time the path bias has been shown to be present in very young speakers of a V-framed language, a result confirming the assumption that these biases are tightly coupled with the internal composition of the motion verb lexicon. English-speaking 3-year-olds and 5-year-olds do not show a reliable manner lexicalization bias (for reasons that, we believe, have to do with the manner dimension in our stimuli); nevertheless, their judgments contrast sharply with those of their Greek peers. Our findings extend prior reports in the literature on the potency of language-specific lexicalization principles (Hohenstein et al., 2004; Maguire et al., 2010; Naigles & Terrazas, 1998; Papafragou & Selimis, 2010b). Unlike prior work that relied on forced-choice tasks to detect the effects of such principles on novel motion verb construals, the present experiments show that (a) learners can spontaneously extract the manner or path dimensions of the stimuli even after a single exposure to a novel motion verb and (b) they can map these dimensions onto verb meanings in accordance with language-specific lexicalization preferences. Thus, our experiments offer particularly clear evidence that language-specific lexicalization principles have an active role in directing novel motion verb learning.

A second major finding is that structure interacts with and overcomes language-specific lexical biases (or the lack thereof). In English, transitive verb syntax encourages path interpretations (despite the manner-oriented lexicalization bias present in adults and the absence of any bias in children). This is especially striking for 3-year-olds, who have not yet acquired path verbs such as *enter*, *exit*, or *traverse* in English but adopt path interpretations of new verbs in response to the semantic demands of transitive frames. In Greek, where there is no conflict between the (path-oriented) motion verb lexicalization bias and transitivity, transitive frames do not seem to boost the path bias for novel verbs. These data contribute to a large body of evidence demonstrating learners' strong commitment to syntax and its semantic implications (Fisher, Gleitman, & Gleitman, 1991; Gillette et al., 1999; Gleitman, 1990; Naigles, 1990; Naigles & Terrazas, 1998; Snedeker & Gleitman, 2004). These data are especially reminiscent of other studies where, for both young children and adults, syntactic cues to verb meaning proved more powerful than either strong language-specific lexical-probabilistic cues (Lidz, Gleitman, & Gleitman, 2003) or persistent contextual cues (Papafragou, Cassidy, & Gleitman, 2007).

A third, related finding is that transitive syntax also promotes path interpretations for novel nonverb predicates across languages. When hearing a structure such as *The X is going acorp the Y* (or its Greek equivalent), both English- and Greek-speaking children and adults in our studies interpret the novel term as a relational, path predicate (i.e., a path preposition) as opposed to a nonrelational, manner predicate. This result extends earlier work showing a role for syntax in the interpretation of static locative prepositions (Fisher et al., 2006; Landau & Stecker, 1990). Together with the results from the transitive verb frame, this result shows that syntactic constraints such as transitivity exert their force in similar ways across different languages and therefore appear truly universal. Such effects are only mitigated when language-specific factors clash with the universal semantic implications of transitivity: Recall that Greek-speaking adults experienced some interference

from the tendency of Greek to express path meanings in both verbs and prepositions when assigning path meanings to novel transitive prepositions; similarly, there was a trend suggesting that English-speaking adults experienced some interference from the manner-oriented lexicalization biases in assigning path meanings to novel transitive verbs.

A fourth major finding is that consistent preferences across and within languages for manner and path interpretations of previously unheard motion predicates are specific to the task of acquiring spatial language (intransitive verb, transitive verb, and preposition conditions). Such preferences largely disappear when participants are not asked to extend motion terms but perform similarity judgments for motion events (no-predicate condition): Under these circumstances, speakers of English and Greek converge in their judgments. This result is important from a methodological viewpoint, since not all prior studies on the cross-linguistic acquisition of motion predicates have ensured that their stimuli were equibiased between path and manner construals (and hence that any path or manner biases in predicate interpretation were not tied to nonlinguistic factors). This result is also important from a theoretical viewpoint, since it shows that lexical and syntactic cues used during spatial word learning function as a zoom lens for spatial event construal—that is, such cues can impose a perspective on events that is distinct from nonlinguistic event representation (see also Fisher, 1996; Fisher, Hall, Rakowitz, & Gleitman, 1994; Gleitman, 1990; Hirsh-Pasek & Golinkoff, 1999; Naigles, 1990; Papafragou & Selimis, 2010b). This finding is consistent with prior work suggesting that the lexical means of encoding motion do not percolate into the conceptual representation of motion events in the minds of speakers of different languages (e.g., Gennari et al., 2002; Papafragou, Massey, & Gleitman, 2003; Papafragou & Selimis, 2010a).

A final finding is that participants obey semantic-geometric constraints on the denotation of motion terms—specifically, they show evidence of recognizing that language does not convey all the representational richness humans possess for encoding location and motion (Landau & Jackendoff, 1993; Talmy, 1985). This is evident in the fact that both young children and adults mostly ignore superficial properties of visual paths when assigning path interpretations to novel motion predicates (either verbs or prepositions). For instance, when interpreting a new verb meaning *go through* or a new preposition meaning *through,* younger and more mature speakers of both English and Greek generally preserve the broad geometric relation between the figure and the ground that it moves through but ignore details of the visual trajectory (e.g., whether the path has leftward or rightward directionality). One exception seems to be the interpretation of prepositions by 3-year-olds in both languages, which tends to be directionality preserving (perhaps as a result of limited experience with the full range of prepositional meanings in language). As before, in tasks that do not involve word learning (as in our no-predicate condition), participants behave differently—specifically, they are more likely to attend to path directionality and treat events that include reverse directional paths as different from each other.

Taken together, these novel results have several broader theoretical implications for the acquisition of spatial language. First, a single predicate (*acorp* in English, *fena* in Greek) uttered as a dynamic motion event is unfolding can be interpreted differently both within and across languages depending on lexical, syntactic, and semantic-geometric factors. This simple fact is recognized by 3- and 5-year-old children as well as adults, who use these factors to fast-map novel motion predicates even after exposure to a single exemplar. Second, some of the factors contributing to the acquisition of motion vocabulary are language specific, and others appear language general. Specifically, in our studies, lexical biases in motion verb content (manner vs. path) encouraged language-distinct verb construals in speakers of S- and V-framed languages (English and Greek, respectively). On the other hand, syntactic and semantic-geometric biases encouraged shared (presumably universal) solutions to the puzzle of acquiring novel verbs and prepositions. Both language-specific and language-general factors seem to be in place already at the youngest children in our sample, suggesting that the acquisition of motion vocabulary needs to consider—as we have tried to do here—how these factors interact and develop in the first years of life.

Our findings leave open several questions that need to be addressed by further research. For instance, our studies throw light on the role of the semantic components of path and manner in the acquisition of motion language. These components have long been assumed to be meaning primitives structuring the spatial lexicon across languages (Talmy, 1985, and later references). However, the extent to which young children spontaneously select these components during language learning was unclear (recall that all prior tasks relied on forced-choice paradigms that pitted manner against path in the construal of motion predicates). Our studies provide evidence that manner and path components are rapidly extracted from motion events and used to build conjectures about newly heard motion terms. It remains to be determined how young children and adults build typological generalizations based on the frequency of path and manner components in their language (Havasi & Snedeker, 2004) and whether the generalizations uncovered in the present article hold across a larger sample of S- and V-framed languages.

Finally, recent linguistic evidence suggests that there is considerable variation in the devices used to express motion even within the traditional V- and S-framed language typological groups (e.g., Beavers et al., 2010; Slobin, 2004; Son, 2007; Son & Svenonius, 2008). It remains to be seen how morphosyntactic properties of languages within these broad classes combine with lexical, structural, and semantic factors to guide learners' hypotheses about how novel motion verbs and prepositions map onto event meanings. It also remains to be seen whether these cross-linguistic regularities extend to other domains of meaning beyond spontaneous motion (see Bunger et al., 2012; Ji, Hendriks, & Hickmann, 2011a, 2011b; Papafragou & Selimis, 2010b, on caused motion events).

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Received March 6, 2013
Revision received March 6, 2014
Accepted April 11, 2014 ■