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Pragmatics and Spatial Language: The Acquisition of *Front* and *Back*

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Across languages, children produce locative *back* earlier and more frequently than *front*, but the reasons for this asymmetry are unclear. On a *semantic misanalysis* explanation, early meanings for *front* and *back* are nonadult (nongeometric), and rely on notions of visibility and occlusion respectively. On an alternative, *pragmatic inference* explanation, visibility and occlusion are simply pragmatic aspects of the meaning of *front* and *back*; the profile of *back* can be explained by the fact that occlusion is more noteworthy compared with visibility. We used cross-linguistic data to test these two hypotheses. In Experiment 1, we examined the production and comprehension of *front/back* by 3- and 4-year-old children and adults speaking two different languages (English and Greek). Children, unlike adults, used *back* more frequently than *front* in both languages; however, no such asymmetry surfaced in the comprehension of the two prepositions. In Experiment 2, both adults and children from the same language groups showed the *front/back* asymmetry when describing a more variable battery of spatial stimuli. Our results support the pragmatic inference hypothesis. We conclude that the emergence of spatial terms does not solely index semantic development but may be linked to pragmatic factors that also shape adults' production of spatial language cross-linguistically.

Keywords: language acquisition, occlusion, pragmatics, projective relations, spatial language

It is widely acknowledged that the acquisition of spatial locatives follows a stable cross-linguistic timetable (e.g., Clark, 1980; E. Clark, 1977; Grimm, 1975; Johnston, 1984; Johnston & Slobin, 1979; Kubena, 1968; Parisi & Antinucci, 1970; Weissenborn, 1981). However, the precise factors involved in this timetable are largely debated. In many cases, patterns of language use in children, especially when these emerge cross-linguistically, have been argued to point to shared (possibly universal) semantic/conceptual asymmetries in underlying representations (Bowerman, 1996). For instance, the early emergence of prepositions such as *in* and *on* has been considered to reflect the early development of the notions of containment and support (Johnston & Slobin, 1979; Piaget & Inhelder, 1967). In other cases, children's uses have been argued to reveal pragmatic facts about the use of language in conversation. For instance, unlike their positive counterparts *in* and *on*, 'negative' containment and support prepositions such as *out* and *off* are used extremely infrequently by children to mark locations (compare "The egg is in the cage" versus "The egg is out of the cage"; Papafragou, Viau, & Landau, 2013). The reason seems to be that the informational contribution of these prepositions is low (they do not specify where something *is*) unless they can be interpreted as indicating a change of location ("The bird is out of the cage" is more felicitous than "The egg is out of the cage") or combine with motion verbs to indicate paths ("The bird went out"; Papafragou et al., 2013). Even though it is often acknowledged that both semantic/conceptual and pragmatic factors shape the way spatial language is used and acquired (e.g., Bowerman, 1996; E. Clark, 1973; Levinson & Wilkins, 2006), adjudicating between the two types of contribution for individual phenomena remains open. Furthermore, the possibility that pragmatic pressures may also yield universal patterns of spatial language acquisition has not been explored in the literature. Our goal in this paper is to add to the discussion of how semantic/conceptual and pragmatic factors contribute to asymmetries in the way children acquire spatial vocabulary cross-linguistically.

The Acquisition of Front and Back

We focus on the acquisition of the locatives *front* and *back* (e.g., "The dog jumped in front of/to the back of the tree"). In several respects, the acquisition of these terms exhibits strong cross-linguistic commonalities. Across languages, locatives corresponding to *front* and *back* generally appear later than locatives corresponding to *in*, *on*, and *under* (Johnston & Slobin, 1979). Furthermore, the acquisition of the terms *front* and *back* is affected by the spatial coordinate system, or Frame of Reference (FoR), in which these terms are embedded. Children's earliest knowledge of *front* and *back*, around age 2, is with respect to their own body (*self-referent intrinsic* FoR; Kuczaj & Maratsos, 1975; Levine &

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Carey, 1982). Around age 3, children acquire *front*/*back* for 'fronted' reference objects (objects with intrinsic front and back parts, e.g., trucks, dolls; *object-referent intrinsic* FoR),[1] and, at a later stage, around age 4, children acquire *front*/*back* for non-fronted objects (objects without inherent front and back parts e.g., boxes, plates), in which front and back sides are defined by projecting one's viewpoint onto the object (*projective* FoR; E. Clark, 1980; Goodglass, Gleason, & Hyde, 1970; Grimm, 1975; Johnston & Slobin, 1979; Kuczaj & Maratsos, 1975; Levine & Carey, 1982; Tanz, 1980; see also Johnston, 1979, 1984; Weissenborn, 1981, for somewhat different estimates).

Most interestingly for present purposes, across different frames of reference, and across languages, locative *back* seems to be produced earlier than *front* (Johnston, 1979, 1984; Johnston & Slobin, 1979; Kubena, 1968). For instance, Johnston and Slobin (1979) asked 2- to 4-year-old children to describe static spatial configurations and found that in Italian, Serbo-Croatian, and Turkish (but not in English) children produced *back* earlier and more frequently than *front* in both the intrinsic and the projective FoRs. In another study, Johnston (1979, 1984) tested children of the same ages in a more interactive paradigm in which children had to help a puppet locate missing objects. She found that *back* was produced earlier than *front* in all FoRs, and that the age of production of *back* varied depending on the visibility of the located object. Specifically, in configurations where the located object was behind a taller (nonfronted) reference object, and thus occluded, children produced *back* frequently from a young age. By contrast, in configurations where the located object was behind a virtually flat reference object, and, thus, visible, children did not produce *back* until much later.

Accounting for the Front/Back Asymmetry

How should the asymmetry between *front* and *back* be explained? One possibility is that children's use of these terms reflects *semantic misanalysis*. Recall that the adult meanings for *front* and *back* are geometric and rely on spatial coordinate axes, such that projective *front* and *back* are semantically symmetrical (and can be paraphrased as "first/second along an axis defined by the observer and the reference object"). On the semantic misanalysis hypothesis, early meanings for *front* and *back* are not adult-like because the corresponding spatial frames of reference, especially those that incorporate the perspective of the observer, are cognitively difficult for young minds (cf. Piaget & Inhelder, 1967; but see Shusterman & Li, 2016b for a more nuanced discussion). Thus, early *front* and *back* are defined instead in terms of the notions of visibility and occlusion respectively, such that they become semantically asymmetrical (Johnston, 1984): projective *back*/*behind* encodes the meaning 'next-to-and-made-inaccessible/invisible-by' and *in front of* means 'next-to-and-visible/accessible' (Johnston, 1984, p. 419). The *front/back* asymmetry follows from this erroneous semantic analysis because occlusion is considered to be more salient compared with visibility for the young learner (Johnston & Slobin, 1979)—for instance, because of "the child's focus on disappearing or inaccessible objects" (Johnston & Slobin, 1979, p. 531) that affects how the child explores and communicates about the world. This proposal about the role of occlusion in children's early representations is consistent with later evidence suggesting that occlusion is one of the earliest spatial concepts in infancy (e.g., Aguiar & Baillargeon, 1999; Casasola & Cohen, 2002; Casasola, Cohen, & Chiarello, 2003; Hespos & Baillargeon, 2001).

According to the semantic misanalysis hypothesis, the meanings of the *front/back* locatives need to undergo semantic reorganization to reach the adult, geometric (coordinate axes-based) meaning (Johnston, 1984). This reorganization is made possible by conceptual development, which enables the child to represent projective front and back configurations in terms of spatial coordinate axes and to overcome the early emphasis on the notions of occlusion and visibility (Johnston, 1984).[2] This proposal is embedded within a more general view on locative expressions that "implicates the role of conceptual growth in determining both their order of emergence and changes in their meaning" (Johnston, 1984, p. 421; cf. also Johnston & Slobin, 1979; Piaget, 1928). Most broadly, this proposal is consistent with the theoretical position that patterns of lexical emergence in child language are a rather straightforward reflection of underlying semantic representations and, by further inference, the conceptual structures that enable such representations (e.g., E. Clark, 1973; Dromi, 1987; Huttenlocher, Smiley, & Charney, 1983; Levine & Carey, 1982).

In the current study, we explore an alternative, *pragmatic inference* hypothesis, according to which children may have adult semantics for the locatives *front* and *back* but pragmatically interpret these locatives as conveying occlusion and visibility of the figure respectively. In many contexts, this communicative inference is justified because reference objects tend to be larger than figure objects (Landau & Jackendoff, 1993; Talmy, 1985). For interesting reasons, the communicative contribution of the semantic, projective meaning of the locatives *front* and *back* ("first/second along an axis defined by the observer and the reference object") is unlikely to be relevant, unless the context invokes the perspective of the observer. For instance, it has been shown that 5- and 9-year-olds adopted coordinate axes interpretations of *front* and *back* only when the perspective of the observer was emphasized by the experimenter's instructions (e.g., "You're going to take a photograph of the man in front of the car. Where should he go?"; Cox & Isard, 1990). Thus, in most contexts, the communicative contribution of the locatives *front* and *back* comes primarily from their pragmatic—and not their semantic—meaning.

According to this analysis, the *front/back* asymmetry is the result of an informational asymmetry between these locatives' pragmatic meanings. Specifically, *back* may be used more frequently than *front* because the occlusion of a figure is (usually) more 'noteworthy' than the visibility of a figure; in many circumstances, the communicative need to mark that an object is hidden is greater than the need to mark than an object is visible (see also

[1] We use the terms *self-referent* and *object-referent* to distinguish the two different *intrinsic* frames (for a discussion of these distinctions see Harris & Strommen, 1979; Shusterman & Li, 2016a). For convenience, in the rest of the paper, when we mention the intrinsic FoR we refer to the object-referent intrinsic FoR.

[2] One could propose that children misanalyze the semantics of *front/back* without assuming that they do so because of conceptual limitations: young learners could simply be incorrect about how to draw the line between semantic and pragmatic meaning. The theorizing and experimentation in the present paper also bear on this proposal, as long as it assumes that children (but not adults) take occlusion and visibility to be part of the semantic content of *front/back*.

Hill, 1991, p. 177; Tanz, 1980, p. 41; Weissenborn, 1981, p. 262). The pragmatic contribution of *front* seems to have the further disadvantage that visibility can be conveyed by several other spatial expressions (i.e., it is not unique to *front*), whereas occlusion seems to be restricted to *back* and a few other expressions (in English, mostly *in* and *under*). Given that, in production, speakers are called to choose the locative that best describes a spatial location from a range of alternatives, *front*, in many cases, might not be the only (or the most) appropriate alternative.

On this proposal, visibility and occlusion inferences from *front/back* uses are no different from other pragmatic inferences from the use of spatial language. For instance, the English preposition *in* and related containment expressions across languages can be used to convey related but distinct relations such as full containment ("coffee in a cup") or partial containment ("pencil in a cup"), depending on one's knowledge about the specific objects in the scene (Herskovits, 1985; Levinson, 1995, 2000). Importantly, although such meanings are closely associated with the preposition *in*, they are not part of its semantics. Perhaps more relevantly, the preposition *in* (and other prepositions such as *under*) can also convey occlusion depending on the specific properties of the figure and ground object (*in the box* conveys occlusion but *in the cage* does not). In theoretical terms, occlusion for *back* and visibility for *front*, together with other pragmatic inferences in spatial language use, could be analyzed as conversational implicatures (Grice, 1975) or contextual enrichments of literal meaning (Sperber & Wilson, 1986) that are cancelable or removable under appropriate circumstances (e.g., "Harry, wearing an invisibility cloak, stood in front of the castle"; "The suspect appeared nervous behind the one-way mirror").

So far arguments for the semantic misanalysis hypothesis have been mostly based on production studies, but evidence from those studies is, in fact, inconclusive. For instance, the findings that *back* is used before *front* and that the earliest occurrences of *back* involve hidden located objects (see Johnston, 1979, 1984) are compatible with both the semantic misanalysis hypothesis (on which early *back* semantically encodes occlusion) and the pragmatic inference hypothesis (on which early *back* is typically used to pragmatically convey occlusion). Furthermore, comprehension studies have produced mixed results, with some studies finding earlier comprehension of *back* compared with *front* (E. Clark, 1980; Levine & Carey, 1982; Tanz, 1980)—in accordance with the semantic misanalysis hypothesis—and others reporting simultaneous acquisition of *front* and *back* (Kuczaj & Maratsos, 1975; Walkerdine, 1975). Finally, direct tests of the conceptual underpinnings of *front* and *back* are vanishingly rare, and those that exist do not address the question of whether there is conceptual evidence supporting the asymmetry (see Johnston, 1979; Levine & Carey, 1982). To summarize, at present, both the precise extent of the *front/back* asymmetry in child language and its origins remain open.

The *front/back* asymmetry is a particularly straightforward case study for assessing semantic/conceptual and pragmatic factors as explanations for an attested developmental sequence in spatial language. Furthermore, methods of dividing the labor between these two explanations have the potential to extend beyond the domain of *front/back* terms to the acquisition of spatial language more generally.

Current Studies

In the current paper, we report a series of experiments on the acquisition of *front/back* with the aim of clarifying whether there is a developmental asymmetry and, if so, what its origins are. We focus on projective Front/Back relations that hold between objects that lack intrinsic front and back facets. Recall that *front/back* uses in the projective frame of reference are among the last children acquire: most studies report that children begin to acquire projective *front/back* around age 4 or later (see Grimm, 1975; Harris & Strommen, 1979; Johnston & Slobin, 1979; Levine & Carey, 1982; Walkerdine, 1975; Weissenborn, 1981). We therefore compare semantic knowledge of projective *front/back* in children below and above this age.

Unlike prior work that focused on static locatives, the current set of studies examines the acquisition of *front/back* in the context of dynamic motion events where front and back relations are parts of motion paths (where the figure moves *in front of/behind* the reference object). To ensure that our conclusions have cross-linguistic validity, we compare two languages (English and Greek) that differ in the ways they encode motion paths. English is a "satellite-framed" language (Talmy, 1985), because it typically encodes path information in prepositions or particles (e.g., *into*, *behind, in front of*). Conversely, Greek is a "verb-framed" language (ibid.) because it encodes path information mainly in the verb and less often in prepositions or particles. Thus, even though Greek has a pair of *front/back* prepositions (*piso/brosta*), we expect Greek speakers to use them less frequently overall compared with English speakers. Such cross-linguistic facts may affect how the *front/back* asymmetry is manifested: for instance, the asymmetry may be weaker or nonexistent in Greek learners' (potentially limited) preposition use compared with English learners. Thus, motion paths can be a powerful lens through which to examine the linguistic encoding of Front/Back configurations across the clause.

Assuming that the *front/back* asymmetry surfaces in our child data, our studies seek to distinguish between the two alternative explanations of the asymmetry outlined in the previous section. Recall that both the semantic misanalysis and the pragmatic inference hypotheses link the *front/back* asymmetry to the distinction between visibility and occlusion but do so in different ways. This leads to several contrasting predictions.

First, the two hypotheses disagree about the scope of the *front/back* asymmetry. If the asymmetry is linked to children's early (incorrect) semantics, as proposed by the semantic misanalysis hypothesis, it should arise in both production and comprehension. If, however, the *front/back* asymmetry is the result of the asymmetric informational contribution of the pragmatic meanings of occlusion and visibility, as postulated by the pragmatic inference hypothesis, the asymmetry may not arise in tests of children's comprehension of the semantics of *front/back* terms. In Experiment 1a (production) and 1b (comprehension) we test these predictions in closely matched tasks.

Second, the two hypotheses have distinct expectations about how size differences between the figure and the reference object should affect *front/back* use. If the asymmetry is attributable to children's early, functional meanings for the prepositions *front* and *back*, as posited by the semantic misanalysis account, size differences between the figure and the reference object should affect children's production and comprehension of these locatives by highlighting such "functional consequences" (Johnston, 1984, p. 408). Specifically, *back* should be used more frequently and understood better in contexts where a large reference object fully occludes the figure compared with contexts where there is only minimal occlusion of the figure; no such difference should exist for *front* because the size of the reference object does not affect the visibility of the figure. Alternatively, if the *front*/*back* asymmetry is driven by a pragmatic bias, as posited by the pragmatic inference account, the relative size (and occluding effect) of the reference object might affect the likelihood that children produce *back* but should not affect children's comprehension of the literal, semantic meaning of *back* (e.g., their judgments of whether *back* truthfully applies to a spatial configuration or not). In Experiments 1a and 1b we manipulate the size of the reference object to test these predictions.

Third, the two hypotheses disagree about the generalizability of the *front*/*back* asymmetry across populations and phenomena. If the asymmetry is attributable to early, immature meanings for the prepositions *front* and *back* (i.e., visibility and occlusion), as proposed by the semantic misanalysis account, only children should use *back* more often than *front*; adults, however, who have by definition mature (geometric) spatial semantics, should use the two expressions equally frequently. Alternatively, if the *front/back* asymmetry is driven by the fact that *back* typically conveys an inherently noteworthy pragmatic meaning (i.e., occlusion) but *front* does not, as proposed by the pragmatic inference account, adults—just like children—might also exhibit the asymmetry in their speech, at least in some contexts. Furthermore, the asymmetry might generalize beyond the prepositional system to other spatial expressions of occlusion/visibility (e.g., verbs) in both children's and adults' speech. In Experiment 2 (and, to some extent, 1a) we test this prediction.

Experiment 1a

In Experiment 1a, 3- and 4-year-old children and adults described motion events involving a figure (a soccer ball) and a schematic reference object. Of interest was whether Back motion paths would elicit corresponding prepositions to a higher rate compared with Front paths. We manipulated the size of the reference object, a factor that has been used to provide support to the semantic misanalysis account of *front/back* (Johnston, 1984). Specifically, for half of the Front and Back motion events, the reference object was taller and wider than the figure and for the other half, shorter or narrower than the figure. Thus, in the case of Back paths, the figure either became fully occluded (when the reference object was taller and wider) or only minimally occluded (when the reference object was shorter/narrower). In the case of Front paths, the figure remained continuously visible regardless of the size change. Of interest was whether this manipulation would affect choice of *front* and especially *back*.

Method

Participants. Participants were 60 native English speakers and 60 native Greek speakers. They fell into three age groups; 3-year-old children, 4-year-old children, and adults, with 20 participants in each age group for each language. This sample size for each age group was chosen before the study began to reflect the number of Greek-speaking participants we could find within a month of international travel. [Post hoc power analysis by simulation using the *simr* package (Green & MacLeod, 2016) in R Project for Statistical Computing (R Development Core Team, 2012), indicated that the study with the given sample size (n = 120) had 90% observed power to detect the theoretically most important higher-order interaction (i.e., Relation by Age).] In the group of English participants, 3-year-olds were between the ages of 3;0 and 4;1, with a mean age of 3;8, and 4-year-olds were between the ages of 4;3 and 5;0 with a mean age of 4;8. The children were recruited at local daycares and came from primarily middle-class families. There was an almost equal number of boys and girls (Female = 19). The English-speaking adults were undergraduate students recruited from the University of Delaware subject pool (range = 18–21, M = 20, Female = 12). They received course credit for their participation. In the group of Greek participants, 3-year-olds were between the ages of 3;0 and 4;2, with a mean age of 3;9, and 4-year-olds were between 4;3 and 5;0, with a mean age of 4;8. The children were recruited at daycares in middle-class neighborhoods in Athens, Greece, or tested at their homes. There was an almost equal number of boys and girls (Female = 19). The Greek-speaking adults were mostly undergraduate and graduate students at the University of Athens, Greece (range = 18–40, M = 26, Female = 12). They received 10 euros for their participation. All Greek data were coded by a native Greek speaker. Approval for testing these participants (as well as those of Experiment 2) had been obtained from the University of Delaware Institutional Review Board (project title: "The interface between language and spatial cognition," protocol number 165481).

Materials. The stimuli for the production task consisted of a total of 36 dynamic motion events presented in Microsoft PowerPoint. Each event consisted of a Figure, which was always the same soccer

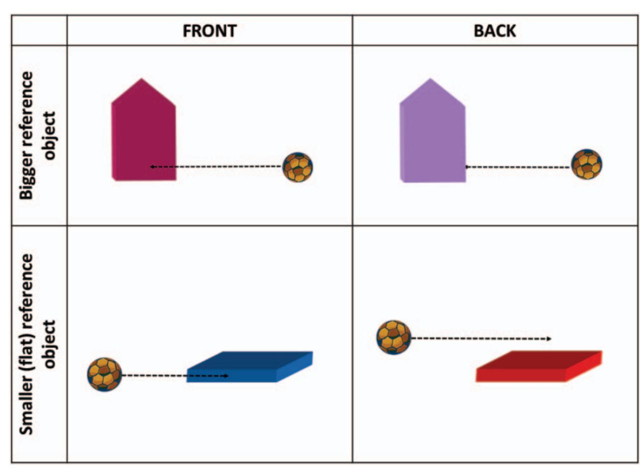

Figure 1. Examples of motion events for the Front and Back relations in Experiments 1a and 1b split by reference object size (Bigger, Smaller). The arrows show the direction of the motion. Back relations involved full occlusion of the figure when the reference object was Bigger but only minimal occlusion when the reference object was Smaller. The reference objects for Front and Back relations were identical except for their color. The actual stimuli were shown against a light blue background. See the online article for the color version of this figure.

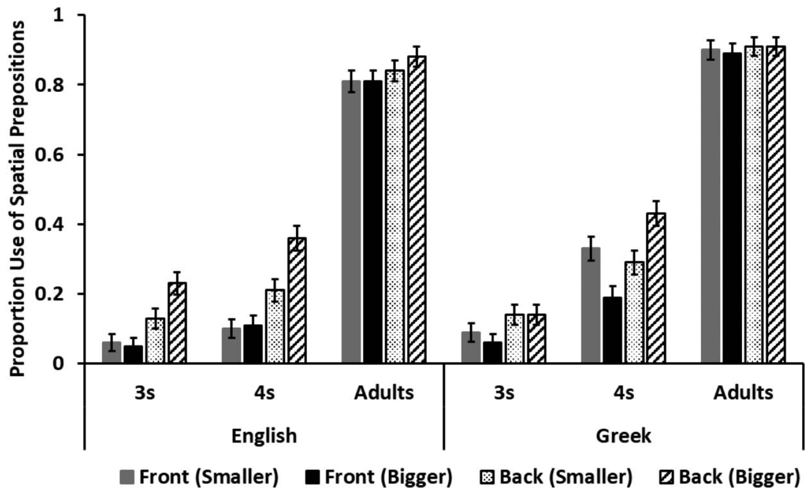

Figure 2. Proportion of target prepositions produced by English and Greek speakers for the Front and Back relations per size of reference object (Bigger, Smaller) in Experiment 1a. Error bars represent standard error.

ball, and a Reference object, which was selected from a set of simple, abstract 3D objects. We chose to use very simple schematic stimuli to elicit only or mainly path information (even from speakers of a language such as English which regularly encodes manner of motion) and to minimize cross-linguistic encoding differences for object names.

The motion events depicted a total of seven different spatial relations. Test events included the relations Front (Figure going IN FRONT OF the Reference object) and Back (Figure going BEHIND the Reference object), with eight exemplars each. For consistency, these exemplars were identical for both relations except for the color of the Reference object and the endpoint of the motion path (IN FRONT OF/BEHIND; Figure 1). Within each relation, the size of the Reference object was manipulated. For half of the exemplars the Reference object was taller and wider than the Figure, and for the other half it was shorter or narrower than the Figure. This manipulation allowed for stimuli depicting the Back relation to vary in terms of whether they involved occlusion of the Figure (when the Reference object was taller and wider) or lack of occlusion (when the Reference object was shorter or narrower). Stimuli depicting the Front relation never involved occlusion of the Figure.

Filler events included the relations Into, Onto, Under, To Right Side, and To Left Side, with four exemplars each. The motion events lasted for three seconds, and then the end state of the event remained on the screen until a key was pressed.

A pseudorandom presentation order was used to ensure that no exemplars of the same spatial relation were within three scenes of each other. A reverse order was also created, so that half of the participants received the original and half the reverse order.

Procedure. The adult participants were told that they would see a series of motion events involving a ball and another "toy." After viewing each event, the participants had to describe what the ball did in each event. The adult participants performed one practice trial.

For the children, the procedure was slightly different. First, the children were told that they were going to play a game where animals play with balls and "toys." They were then shown a screen with all Reference objects, and were instructed that those were all "toys." Second, to help the children maintain attention, a slide with a small cartoon animal in one of the bottom corners was presented before each motion event. The experimenter said, "Look at the (animal)! Let's see what the (animal)'s ball will do!." The motion clip was then played and remained on the screen; then the experimenter asked the child to describe what the animal's ball did. The children completed at least three practice trials before beginning the experiment. Practice trials were identical to test trials but they involved relations not tested in the main trials (i.e., Over, Around, Across).

Coding. Each linguistic description for the Front and Back relations was coded for the presence of a target preposition. For Front, the target prepositions were *in front of/to front of* in English and *brosta apo/brosta sto* 'in front of' in Greek. For Back, the target prepositions included *behind*, *to back/in back* in English and *piso (apo)/apo piso* 'behind' in Greek.[3]

Results

We measured participants' use of *front/back* prepositions. This measure was a binary outcome variable coded as "1" or "0." The data were analyzed using multilevel logistic mixed-effects modeling with crossed random intercepts for Subjects and Items (Baayen, 2008; Baayen, Davidson, & Bates, 2008). This analytical approach allows for Subjects and Items to be treated as random factors in a single model and for the appropriate treatment of categorical data (Jaeger, 2008; cf. Barr, 2008). All models were fit using the *glmer* function of the *lme4* package (Bates, 2005; Bates, Maechler, & Bolker, 2011; Bates, Maechler, Bolker, & Walker, 2015; Bates & Sarkar, 2007) in the R Project for Statistical Computing (R Development Core Team, 2012). Models were fitted with Maximum Likelihood of parameters (ML), with log-likelihood ratio tests ascertaining model fit. Interactions that did not significantly improve model fit were removed from the model.

[3] In English and other languages, the preposition *back* is homonymous with the related body part (a fact that may boost its frequency in the adult input; Johnston & Slobin, 1979; Levine & Carey, 1982) but in Greek, there is no such homonymy.

Table 1
Parameter Estimates for Use of Prepositions in Experiment 1a

Effects	Estimate	*SE*	*z*
Intercept	−1.03	0.32	−3.26**
Relation (Back vs. Front)	−1.17	0.42	−2.81**
Object size (Bigger vs. Smaller)	−.17	0.41	−0.40
Age (Children vs. Adults)	−6.19	0.59	−10.58***
Age (3- vs. 4-year-olds)	1.50	0.61	2.45*
Language (English vs. Greek)	0.76	0.49	1.53
Relation (Back vs. Front): Object size (Bigger vs. Smaller)	−1.25	0.83	−1.51
Relation (Back vs. Front): Age (Children vs. Adults)	−1.22	0.39	−3.12**
Relation (Back vs. Front): Age (3- vs. 4-year-olds)	−.17	0.45	−0.38
Object size (Bigger vs. Smaller): Age (Children vs. Adults)	0.11	0.38	0.28
Object size (Bigger vs. Smaller): Age (3- vs. 4-year-olds)	0.22	0.43	0.50
Object size (Bigger vs. Smaller): Language (English vs. Greek)	−0.64	0.34	−1.88
Relation (Back): Obj. size (Bigger vs. Smaller): Age (Ch vs. Ad)	−1.74	0.78	−2.24*
Relation (Front): Obj. size (Bigger vs. Smaller): Age (3s vs. 4s)	−1.14	0.88	−1.30
Relation (Back): Obj. size (Smaller): Language (English vs. Greek)	0.90	0.49	1.83
Relation (Front): Obj. size (Bigger): Language (English vs. Greek)	0.83	0.51	1.65

* $p < .05$. ** $p < .01$. *** $p < .001$.

The use of *front* and *back* prepositions was analyzed with a model that included Subjects and Items as crossed-level random intercepts. Figure 2 summarizes the data. All fixed predictors were included in the final model: Relation (Front, Back) and Reference Object Size (Bigger, Smaller) as first-level predictors, and Age (3-year-old, 4-year-old, Adult) and Language (English, Greek) as second-level predictors. To decide what interactions best fit these data, we conducted chi-square tests of the change in −2 restricted log likelihood. The final model included all the interactions that significantly improved model fit and those two-way interactions that were included in three-way interactions. The best fit for these data was a model that included two-way interactions between Relation and Reference Object Size, Relation and Age, Relation and Language, Reference Object Size and Age, and Reference Object Size and Language,[4] and two three-way interactions of Relation, Reference Object Size and Age, and Relation, Reference Object Size and Language. The fixed effects of Relation and Object Size were coded with centered contrasts (-.5, .5) and the fixed effect of Age was analyzed with two simple contrasts comparing adults to children (c_1: −.66, .33, .33) and 4-year-olds to 3-year-olds (c_2: 0, −.5, .5). The same coding strategy was followed in all the following analyses.

Table 1 presents the parameter estimates for the multilevel model of use of prepositions. Results showed an effect of Relation, with Back prepositions used more frequently than Front prepositions (M_{Front} = .37, M_{Back} = .46). The model also showed an effect of Age, with adults being more likely to use prepositions than children (M_{Ad} = .87, M_{Ch} = .18) and 4-year-olds more likely to use prepositions than 3-year-olds (M_4 = .25, M_3 = .11). The analysis also yielded an interaction between Relation and Age, which was attributable to the fact that adults mentioned Front and Back prepositions equally frequently (M_{Front} = .85, M_{Back} = .88) but children mentioned Back prepositions more frequently than Front prepositions (M_{Front} = .13, M_{Back} = .24).

Finally, there was a three-way interaction of Relation, Reference Object Size, and Age: children mentioned Back prepositions more frequently when the reference object was bigger than the figure compared with when the reference object was smaller and hence did not fully occlude the figure (Back: M_{Bigger} = .29, $M_{Smaller}$ = .19) but for adults, the size of the reference object did not affect mention of prepositions (Back: M_{Bigger} = .89, $M_{Smaller}$ = .88). The size of the reference object did not affect mention of Front prepositions in any age group. The model did not yield any other effects of interactions.

Discussion

Experiment 1a compared the use of *front*/*back* prepositions in 3-year-old, 4-year-old, and adult speakers of English and Greek. The present data demonstrate a developmental trajectory, with 4-year-old children producing these prepositions more frequently compared with 3-year-old children cross-linguistically, and with production still low even in the older group of children (e.g., see also Grimm, 1975; Harris & Strommen, 1979; Johnston & Slobin, 1979; Walkerdine, 1975; Weissenborn, 1981). Our data also clearly support the *front*/*back* asymmetry: 3- and 4-year-old children in both languages used the preposition *back* more frequently than the preposition *front.*[5] Interestingly, the asymmetry was limited to children's descriptions of motion paths; adults used both prepositions equally frequently. Furthermore, 3- and 4-year-old children in both languages mentioned *back* more frequently when the figure was fully occluded by a larger reference object compared with when it was not but no such difference was found for adults (or for the preposition *front* in any age group). These patterns are consistent with prior reports on Front/Back expressions cross-linguistically that have been used to argue in favor of the semantic misanalysis account in children (cf. Johnston & Slobin, 1979; Johnston, 1984). However, it remains an open possibility that this finding was attributable to the nature of our

[4] The interaction between Age and Language was not included in the final model because (a) did not significantly improve model fit, $\chi^2(1)$ = .85, p = .65, and (b) it was not included in the three-way interactions that did significantly improve model fit.

[5] We use *front* and *back* here (and in the rest of the paper) to refer to Front and Back prepositions in both English and Greek.

stimuli; the relative uniformity of the motion events and the somewhat restricted range of spatial relations might have led to very high use of both target prepositions in adults, potentially masking asymmetries in their distribution that would be consistent with the pragmatic inference account. We revisit this issue in Experiment 2 where we test production of spatial language using a broader array of motion events.

An unexpected aspect of our data was that, despite the well-documented typological differences in path encodings between English and Greek (e.g., Papafragou, Massey, & Gleitman, 2002, 2006), English and Greek speakers were equally likely to use prepositions (and adults in both groups seem to have done so in the vast majority of their utterances). We suspect that this finding was again attributable to the nature of our stimuli that highlighted Front/Back relations and may have led to contrastive use of prepositions to carry the main spatial meaning. We return to this issue in Experiment 2.

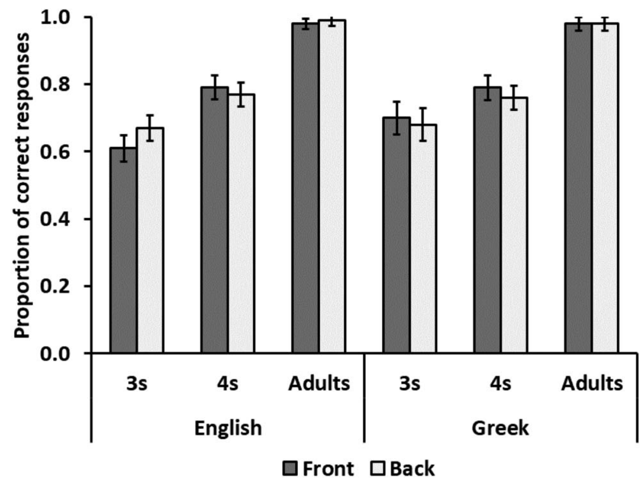

Figure 3. Proportion of correct responses for Front and Back prepositions given by English and Greek speakers in Experiment 1b. Error bars represent standard error.

Experiment 1b

Experiment 1b used the same participants and stimuli as Experiment 1a but targeted comprehension of *front* and *back*. Specifically, participants were given a version of a Truth Value Judgment task (Crain & Thornton, 1998) where they had to judge whether a motion path could be described by a Front or Back term.[6] Recall that, on the semantic misanalysis hypothesis, the *front*/*back* asymmetry observed in children's production in Experiment 1a should extend to children's comprehension: if children erroneously include visibility and occlusion within the stable, semantic content of these expressions, and have a bias to attend to occlusion more, their comprehension of Back (occlusion) prepositions should be better than their comprehension of Front (visibility) prepositions. Relatedly, children's willingness to accept *back* for a given configuration in comprehension should be influenced by whether the reference object is large enough to fully occlude the figure, mirroring the results from production.

By contrast, on the pragmatic inference hypothesis, the bias to use *back* more frequently than *front* in production is due to the differential informational weight of the pragmatic overtones (occlusion vs. visibility) of the prepositions' basic semantic meaning. Because such pragmatic overtones are highly context-dependent, there is no reason to expect that they should surface in a comprehension task that targets the basic semantic content of Front/Back terms. According to this line of reasoning, children should be equally likely to accept *front* and *back* in a semantic comprehension task, as long as the motion path satisfies the terms' semantic (geometric) content. Similarly, effects of reference object size observed in the earlier production task should be irrelevant for assessments of whether or not different motion paths satisfy the semantics of Front and Back terms in comprehension.

Method

Participants. Participants were the same as in Experiment 1a and completed the comprehension task after the production task. Adults completed both tasks on the same day. Children completed the tasks on separate days, with certain exceptions ($n = 4$). A few children did not contribute comprehension data because of fussiness ($n = 5$) or unavailability ($n = 4$). Additionally, comprehension data from 3 children (1 English and 2 Greek speakers) were excluded because these children always gave either *Yes* or *No* answers throughout.

Materials. The same motion events used in the production task were also used in the comprehension task, except that only 2 exemplars for the relations Left and Right were included, for a total of 32 motion events. A new pseudorandom presentation order was created, such that no exemplars of the same spatial relation were within three scenes of each other. This order was then reversed. Each participant was assigned to one of the two orders.

Procedure. The procedure for the comprehension task was the same for children and adults. Participants were told that they would play a game in which they would have to help a magician learn new magic tricks. The English instructions were as follows: "The magician wants to learn how to make a ball go in front of or behind the toy. If he does what he says he will get a prize!" (Greek version: "O magos theli na mathi pos na kani tin bala na pai mprosta i piso apo to pehnidi. An kani afto pu lei tha perni ena vravio!"). At the beginning of each trial, participants were shown a slide with a small cartoon boy-magician. The experimenter then said, "Look at the magician! Let's see what he is going to say!" (this step was omitted for adults). Participants then heard one of two prerecorded test sentences: "I'll make the ball go in front of/behind the toy" (Greek version: "Tha kano ti bala na pai mprosta/piso apo to pehnidi"). After this, participants watched a motion event and were asked to decide if the magician should get a prize or not ("Did he do what he said? Should he get a prize?"). The correct response for stimuli that depicted Back or Front

[6] The present paradigm was chosen to address conflicting findings in the literature. First, because some studies, when reporting asymmetries between *front* and *back*, collapse across different frames of reference, here we focused only on projective *front*/*back*. Second, unlike prior work that assessed *front*/*back* knowledge in action-based tasks (e.g., E. Clark, 1980; Kuczaj & Maratsos, 1975; Levine & Carey, 1982), which may have encouraged children's use of nonlinguistic strategies based on the functional properties of the reference objects (see E. Clark, 1980; Levine & Carey, 1982, p. 655, for discussion), here we used the Truth Value Judgement task to target children's semantic knowledge.

Table 2
Parameter Estimates for Correct Responses in Experiment 1b (All Configurations)

Effects	Estimate	*SE*	*z*
Intercept	2.51	0.19	13.37***
Relation (Back vs. Front)	−0.11	0.12	−0.92
Age (Children vs. Adults)	−3.76	0.38	−9.82***
Age (3- vs. 4-year-olds)	0.79	0.31	2.53*
Language (English vs. Greek)	−0.05	0.28	−0.16

* $p < .05$. *** $p < .001$.

configurations was always "yes" (16 responses), whereas the correct answer for stimuli that depicted all other relations was always "no" (16 responses). To ensure that children understood the task and were capable of saying both "yes" and "no," they received four practice trials with the prepositions *onto* and *under* (for two of those the correct answer was "yes"; for the other two it was "no"). Adults performed only two practice trials. The experimenter provided appropriate feedback for practice items.

Results

To analyze *front* and *back* comprehension, we measured the accuracy of participants' responses ("correct" = 1, "incorrect" = 0) for all trials (including Front and Back configurations, to which the answer was "yes," and all other configurations, to which the answer was "no"). This binary outcome variable was analyzed with a model that included Subjects and Items as crossed-level random intercepts. The best fit for this data was a model that included Relation (tested in question) as a first-level predictor and Age and Language as second-level predictors. Figure 3 summarizes the data. Table 2 presents the parameter estimates for the multilevel model of proportion of correct responses. The model yielded a significant effect of Age, with adults showing greater understanding of the prepositions *front* and *back* than children (M_{Ad} = .98, M_{Ch} = .72) and 4-year-olds showing better understanding than 3-year-olds (M_4 = .78, M_3 = .66). No other effect was significant.

To investigate whether size differences between the figure and the reference object affect the *front/back* asymmetry, we analyzed only trials with Front/Back configurations (for which size had been manipulated; see Figure 4). The correct semantic response for these trials was always "yes." Because accuracy for Front/Back configurations in the adult group was extremely high (M_F = .99, M_B = .99), adult data did not have enough variability and were not included in this analysis. (An assessment of model fit based on chi-square tests of the change in −2 restricted log likelihood for the adult data separately showed that no model other than the empty model with random intercepts for Subjects and Items was a good fit for these data.) The best fit for the child data was a model that included Relation, Reference Object Size, Age, and Language and all their interactions as fixed factors and Subjects and Items as random factors. Table 3 illustrates the parameter estimates for this model. Results showed a main effect of Reference Object Size: participants' accuracy was higher when the reference object was bigger than the figure (M_{Bigger} = .81, $M_{Smaller}$ = .73). There were also two significant interactions: a three-way interaction of Relation, Age, and Language and a four-way interaction of Relation, Object Size, Age, and Language. Further exploration of these interactions showed that Greek-speaking 3- and 4-year-olds were more accurate when the reference object was bigger than the figure for both Front and Back configurations (β = .54, *SE* = .25, *z* = 2.16, *p* = .03; M_{Bigger} = .84, $M_{Smaller}$ = .77) and so were English-speaking 3-year-olds (β = .74, *SE* = .37, *z* = 2.03, *p* = .04; M_{Bigger} = .72, $M_{Smaller}$ = .61). English-speaking 4-year-olds, however, only demonstrated this tendency for Front configurations (β = 2.28, *SE* = .98, *z* = 2.33, *p* = .02; M_{Bigger} = .94, $M_{Smaller}$ = .76) but not for Back configurations (M_{Bigger} = .81, $M_{Smaller}$ = .81).

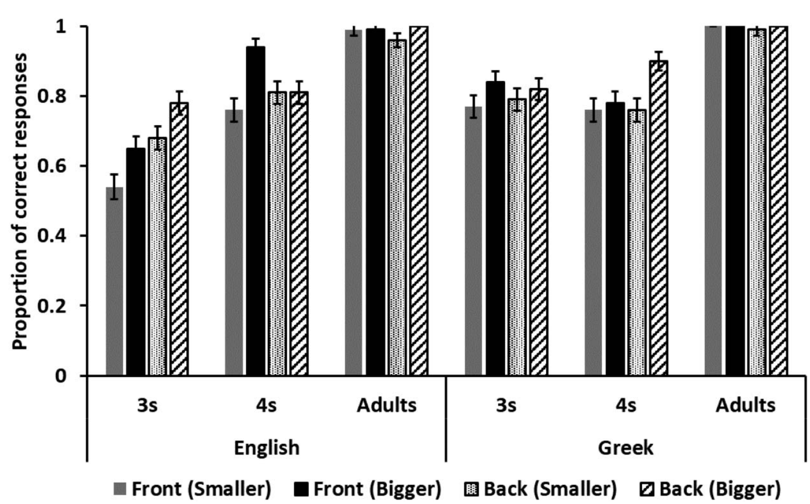

Figure 4. Proportion of correct responses given by English and Greek speakers in the Front/Back configurations of Experiment 1b split by the size of the reference object (Bigger, Smaller than figure). Error bars represent standard error.

Table 3
Parameter Estimates for Correct Responses in Experiment 1b (Only Front/Back Configurations)

Effects	Estimate	*SE*	*z*
Intercept	1.84	0.23	7.92***
Relation (Back vs. Front)	−0.20	0.20	−1.02
Reference Object Size (Bigger vs. Smaller)	0.73	0.21	3.56***
Age (3- vs. 4-year-olds)	−0.82	0.44	−1.88
Language (English vs. Greek)	0.24	0.44	0.55
Relation (Back vs. Front): Object size (Bigger vs. Smaller)	0.35	0.41	0.85
Relation (Back vs. Front): Age (3- vs. 4-year-olds)	−0.45	0.36	−1.26
Object size (Bigger vs. Smaller): Age (3- vs. 4-year-olds)	−0.34	0.36	−0.98
Relation (Back vs. Front): Language (English vs. Greek)	−0.27	0.37	−0.72
Object size (Bigger vs. Smaller): Language (English vs. Greek)	−0.26	0.36	−0.72
Age (3- vs. 4-year-olds): Language (English vs. Greek)	1.15	0.87	1.32
Relation (Back vs. Front): Obj. size (Bigger vs. Smaller): Age (3s vs. 4s)	−0.25	0.71	−0.35
Relation (B vs. F): Obj. size (Bigger vs. Smaller): Language (En vs. Gr)	−1.36	0.75	−1.80
Relation (B vs. F): Age (3s vs. 4s): Language (English vs. Greek)	2.25	0.71	3.15**
Obj. size (Bigger vs. Smaller): Age (3s vs. 4s): Language (En vs. Gr)	−0.05	0.71	−0.07
Relation (B vs. F): Obj. size (B vs. Sm): Age (3s vs. 4s): Language (En vs. Gr)	3.71	1.42	2.61**

** $p < .01$. *** $p < .001$.

Discussion

Our findings suggest that the comprehension of *front/back* in both English and Greek speakers is developing between the ages of 3 and 4 and is still not adult-like in the older age group. However, as inspection of Figures 2 and 3 shows, comprehension of these locatives was much better than children's low rates of *front/back* production might suggest. Most relevantly for present purposes, unlike the production results, the comprehension data show no *front/back* asymmetry: although children were more likely to produce *back* than *front* when asked to describe motion scenes in Experiment 1a, their understanding of *front* and *back* for the same scenes in Experiment 1b was equivalent (as was the case in the adult data). This result is unexpected on the semantic misanalysis account but is entirely consistent with the pragmatic inference account.

Although participants did not show asymmetric understanding of *front* and *back*, the size of the reference object affected children's comprehension of these locatives (adults were at ceiling for all configurations) but not in an entirely consistent manner across age and language groups: Greek-speaking 3- and 4-year-olds and English-speaking 3-year-olds showed better comprehension of *front* and *back* when these were applied to configurations where the reference object was bigger than the figure but English-speaking 4-year-olds exhibited this tendency only for Front (but not for Back) paths. The fact that this tendency was not accompanied by an asymmetry between overall *front* and *back* comprehension and did not involve only the Back relation, where the size of the reference object could result in occlusion of the figure, but involved also (and in English-speaking 4-year-olds exclusively) the Front relation, where the size of the reference object did not affect visibility, is problematic for the semantic misanalysis account. A more likely explanation for the size effect is that it represents the general preference in both language and vision for spatial configurations in which figures are small/moveable and reference objects large/stationary (Landau & Jackendoff, 1993; Talmy, 1985). In a sense, Front/Back configurations in our stimuli, where the reference object was larger than the figure, were better exemplars of the prototypical or 'ideal' concept for *front* and *back* prepositions (see Herskovits, 1985). This semantic property of spatial prepositions (also active in the semantic organization of other concepts, see Armstrong, Gleitman, & Gleitman, 1983) should be distinguished from pragmatic consequences that arise by the use of prepositions in context (i.e., occlusion and visibility in this case, see Herskovits, 1985, for a discussion). We do not currently have an explanation for why reference object size mattered only for the older English-speaking children's comprehension of *front*, not *back*.

Taken together, the data from Experiments 1a and 1b suggest that the advantage of *back* over *front* in children's production (and its sensitivity to reference object size) has pragmatic, not semantic, roots and disappears when children's semantic knowledge of the prepositions is tested.

Experiment 2

In Experiment 2 we revisited the cross-linguistic distribution of Front/Back terms in the speech of preschoolers and adults. We used a battery of stimuli that was similar to that in Experiment 1a but took a number of steps to introduce a wide range of motion configurations. First, unlike Experiment 1a where Front and Back relations had twice as many exemplars as each of the 5 filler spatial relations, in Experiment 2 Front and Back had the same number of exemplars as the other 6 relations in the battery. Second, only half of the exemplars for each relation—including the Front and Back relations—involved goal paths, as in Experiment 1a (e.g., a figure moving *in front of/behind* the reference object). The other half involved source paths (e.g., a figure moving *from front of/from behind* the reference object) that are known to elicit sparser spatial language (Lakusta & Landau, 2005; Papafragou, 2010; Regier & Zheng, 2007).

Experiment 2 had several broad goals. First, we were interested in exploring whether the observations about *front/back* use in Experiment 1a would generalize to young children in the present study, and perhaps also to adults tested with a broader battery of motion scenes (a possibility left open by the pragmatic inference account but excluded by the semantic misanalysis account of how *front/back* are acquired). Furthermore, we wanted to see whether the asymmetry might extend to other expressions such as spatial verbs used to describe Front/Back configurations (see H. Clark, 1973; Fillmore, 1975; Landau, Johannes, Skordos, & Papafragou, 2017; Miller & Johnson-Laird, 1976; Talmy, 1983, on the role of spatial verbs). Finally, we hypothesized that the variation in the type of motion paths in Experiment 2 would elicit a wider array of path descriptions and possibly reveal language-specific encoding patterns that were obscured in Experiment 1a (where English and Greek speakers used Front/Back prepositions to an equal degree).

Method

Participants. Participants were 40 native English speakers and 40 native Greek speakers. They fell into two age groups; children and adults, with 20 participants in each age group for each language. The sample size for each group of participants was defined in accordance to Experiment 1. [Post hoc power analysis indicated that the study with the given number of participants (n = 80) had 100% observed power to detect the theoretically most important higher-order interaction (i.e., Relation by Age).] We included a wide sample of preschoolers in the child group because 3- and 4-year-olds did not differ substantially in terms of the *front/back* asymmetry in our prior experiments. In the group of English participants, children were between the ages of 3;8 and 5;5 with a mean age of 4;6 (Female = 13). The children were recruited at local daycares and came from primarily middle-class families. The English-speaking adults were undergraduate students recruited from the University of Delaware subject pool and received course credit for their participation (range = 19–26, M = 20, Female = 12). In the group of Greek participants, children were between the ages of 3;9 and 5;3, with a mean age of 4;6 (Female = 10). The children were recruited in Evia, Greece and came from middle-class families. The Greek-speaking adults were University students and young professionals recruited in Evia and Athens, Greece (range = 18–40, M = 27, Female = 12). All Greek data were coded by a native Greek speaker.

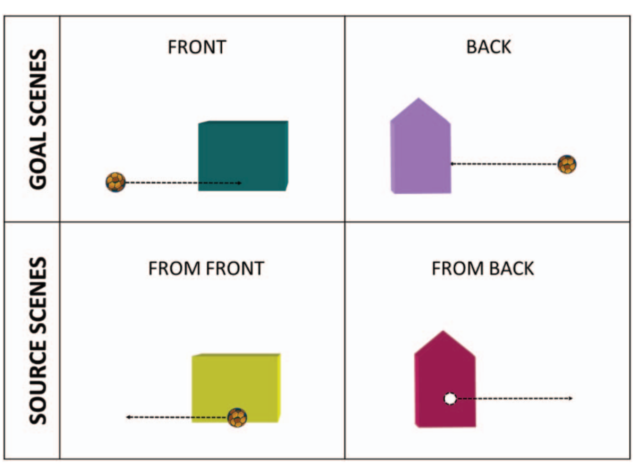

Figure 5. Examples of goal and source versions of motion events for the Front (IN FRONT OF/FROM IN FRONT OF) and Back (BACK/FROM BACK) relation in Experiment 2. The actual stimuli were shown against a light blue background. The arrows show the direction of the motion. (In the beginning of the FROM BACK event the ball was occluded. We use a dotted-line circle to depict the occluded ball. The ball also ended up being occluded at the end of the BACK event.) See the online article for the color version of this figure.

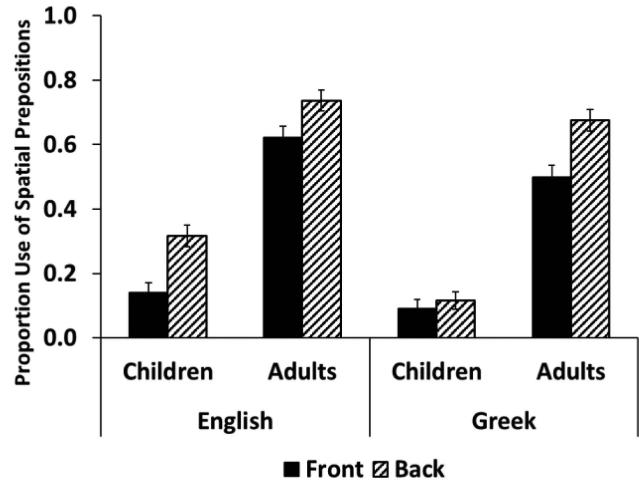

Figure 6. Proportion of (Front/Back) prepositions given by English and Greek speakers for the Front and Back relations in Experiment 2. Error bars represent standard error.

Materials. The stimuli of Experiment 2 consisted of a total of 48 dynamic motion events presented in Microsoft PowerPoint. The events were similar to the events of Experiment 1a, including always the same Figure (i.e., a soccer ball) and schematic reference objects which lacked inherent front and back sides. Compared with Experiment 1a, the Figure was somewhat smaller and hence the motion paths traveled were slightly longer. Another difference from Experiment 1a was that stimuli depicting the Back relation always involved full occlusion of the Figure.

The motion events depicted a total of eight different spatial relations, each with a source and a goal version. These included Front (IN FRONT OF/FROM IN FRONT OF) and Back (BACK/FROM BACK)—see Figure 5 for sample stimuli. The remaining relations were Containment (IN/OUT OF), Cover (UNDER/FROM UNDER), Support (ONTO/OFF OF), Contact (TO/FROM), Vertical Proximity (TOWARDS THE SIDE OF/AWAY FROM THE SIDE OF), and Horizontal Proximity (TOWARDS THE TOP OF/AWAY FROM THE TOP OF). Six events were shown for each relation (three basic exemplars, each with a goal and a source version). The source and goal versions of the same exemplar were identical except for the color of the Reference object and the direction of the motion path. The motion events lasted for three seconds and then the end state of the event remained on the screen until a key was pressed.

A pseudorandom presentation order was used to ensure that no exemplars of the same spatial relation were within three scenes of each other. A reverse order was also created, so that half of the participants received the original and half the reverse order.

Procedure. The procedure was identical to the procedure in Experiment 1a.

Coding. Each linguistic description for the Front and Back relations was first coded for the presence of a target preposition that had to correspond to the type of scene (goal/source). Descriptions for goal scenes were coded following the coding scheme of

Table 4
Parameter Estimates for Use of Prepositions in Experiment 2

Effects	Estimate	*SE*	*z*
Intercept	−0.98	0.30	-3.22^{**}
Relation (Back vs. Front)	−1.04	0.39	-2.69^{**}
Age (Children vs. Adults)	−3.60	0.53	-6.84^{***}
Language (English vs. Greek)	−1.09	0.49	-2.21^{*}

* $p < .05$. ** $p < .01$. *** $p < .001$.

Table 5
Parameter Estimates for Use of Occlusion Expressions in Experiment 2

Effects	Estimate	*SE*	*z*
Intercept	−2.15	0.50	-4.28^{***}
Age (Children vs. Adults)	0.28	0.70	0.40
Language (English vs. Greek)	3.41	0.78	4.37^{***}

*** $p < .001$.

Experiment 1a. For source scenes, target prepositions for Front included *from* (*in*) *front* (*of*) in English and (*apo*) *brosta* (apo) '(from) front (of)' in Greek, and for Back *from behind* in English and *apo piso (apo)* 'from behind (of)' in Greek.

The linguistic descriptions were also coded for the presence of spatial expressions of visibility or occlusion. For the Front relation, there were no expressions encoding visibility. This fact is highly significant, and we return to it in the Results section. For the Back relation, we coded predominantly appearance/disappearance verbs that encoded occlusion (or, more accurately, a change of state from or to occlusion): *disappear* and *hide* (goal scenes), *appear, emerge* (source scenes) in English, and *hanome* 'disappear,' *krivome* 'hide' (goal scenes) and *emfanizome* 'appear' (source scenes) in Greek.

Finally, all linguistic descriptions of Front and Back relations were coded in terms of the total target spatial information they contained (i.e., target preposition or occlusion expression). This was done because there was often overlap in the use of target prepositions and other expressions to describe an event (e.g., in Greek "*I bala krivete piso apo to pehnidi*" "the ball is hiding behind the toy"), so analyzing each separately might not accurately represent the way Front and Back relations are linguistically represented.

Results

Use of front versus back prepositions. The use of Front/Back prepositions to encode the two corresponding relations was analyzed with a model that included Subjects and Items as crossed-level random intercepts. Figure 6 presents the data. The best fit for these data was a model that included Relation (Front, Back) as first-level predictor and Age (Children, Adults) and Language (English, Greek) as second-level predictors (no interaction significantly improved model fit based on chi-square tests of the change in −2 restricted log likelihood). Similarly to Experiment 1a, all fixed effects were coded with centered contrasts. Table 4 presents the parameter estimates for the multilevel model of use of prepositions. The analysis yielded a significant main effect of Relation: participants, overall, mentioned Back prepositions more frequently than Front prepositions ($M_F = .33$, $M_B = .46$). The analysis also yielded a main effect of Age: unsurprisingly, adults used more prepositions than children ($M_{CH} = .17$, $M_{AD} = .63$). Finally, the analysis returned a significant effect of Language in the expected direction: English speakers used more target prepositions than Greek speakers ($M_{ENG} = .49$, $M_{GR} = .34$).

Use of visibility versus occlusion terms. Recall that the present dataset included a great variety of expressions encoding occlusion in Back scenes (e.g., *hide*, *emerge*), but no expressions encoding visibility in Front scenes. To analyze the expressions marking occlusion, we used a model that included Age and Language as a fixed predictors and Subjects and Items as random intercepts (see Figure 7). The parameter estimates for the multilevel model of use of occlusion expressions are shown in Table 5. The model returned a main effect of Language: because the occlusion expressions were mainly verbs, Greek speakers used occlusion expressions more frequently than English speakers ($M_{ENG} = .11$, $M_{GR} = .45$). Crucially, the effect of Age was not

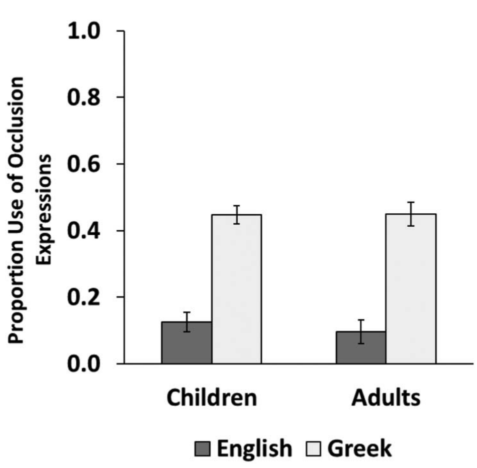

Figure 7. Proportion of Occlusion expressions given by English and Greek speakers for the Back relation in Experiment 2. Error bars represent standard error.

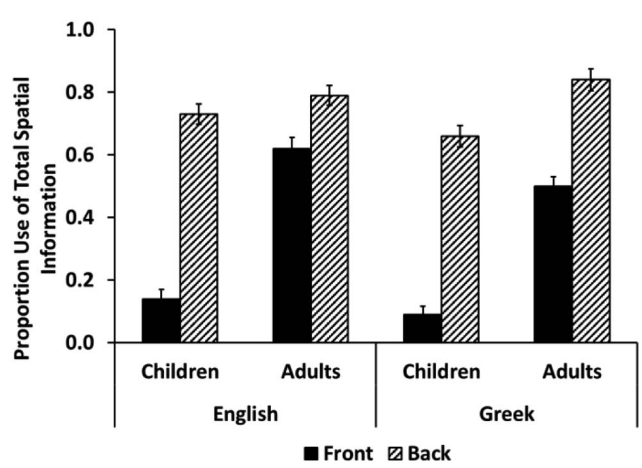

Figure 8. Proportion of total spatial information (prepositions and verbs) given by English and Greek speakers for the Front and Back relations in Experiment 2. Error bars represent standard error.

Table 6
Parameter Estimates for Use of Total Spatial Information in Experiment 2

Effects	Estimate	*SE*	*z*
Intercept	0.20	0.27	0.75
Relation (Back vs. Front)	−3.01	0.41	-7.35^{***}
Age (Children vs. Adults)	−2.12	0.43	-4.95^{***}
Language (English vs. Greek)	−0.50	0.42	−1.20
Relation (Back vs. Front): Age (Children vs. Adults)	−2.45	0.45	-5.48^{***}

*** $p < .001$.

significant: adults used occlusion expressions as frequently as children ($M_{CH} = .29$, $M_{AD} = .27$).

Use of total spatial information to mark front versus back relations. Finally, we analyzed the use of total spatial information (prepositions and occlusion expressions) to mark Front and Back relations. The best fit for these data was a model that included Relation (Front, Back) as a first-level predictor, Age (Children, Adults) and Language as second-level predictors and an interaction between Relation and Age (see Figure 8). Table 6 presents the parameter estimates for the multilevel model of use of total spatial information. Results yielded significant effects of Relation and Age, qualified by an interaction of these two predictors. We followed up this interaction by fitting two separate models for adults and children. We found that spatial information was used more frequently to encode Back compared with Front relations by both age groups, but this difference was greater in children (children: $\beta = -4.33$, $SE = 0.55$, $z = -7.93$, $p < .001$; adults: $\beta = -1.74$, $SE = 0.39$, $z = -4.46$, $p < .001$).

Discussion

Experiment 2 probed the production of *front/back* spatial language by introducing a variety of motion paths. Our goal was to see whether this battery might lead to more differentiated profiles for spatial expressions and highlight cross-linguistic differences. Other major goals were to use the new battery to explore the description of Front and Back scenes beyond the prepositional system in children and adults cross-linguistically.

The new battery produced clear cross-linguistic differences in spatial language: Greek speakers were less likely than English speakers to encode Front/Back motion paths in prepositions (and more likely to do so in spatial verbs). Nevertheless, the basic asymmetry in the use of *front/back* prepositions found in young learners of the two languages in Experiment 1a was replicated in the present data; additionally, the asymmetry was found in adults. Furthermore, the asymmetry extended beyond prepositional semantics: across ages and languages, there was a great variety of expressions (mostly, spatial verbs) encoding occlusion in Back scenes, but no expressions encoding visibility in Front scenes. When the total amount of spatial information produced was taken into account, both children and adults across languages were found to have a bias for encoding Back compared with Front paths (the bias was more pronounced in children whose encoding of Front paths was extremely sparse—see Figure 8).

The above similarities between children's and adults' use of spatial language are hard to reconcile with the semantic misanalysis account, which predicts that only children—and not semantically sophisticated adults—should exhibit a *front*/*back* asymmetry. Moreover, the fact that the asymmetry characterizes additional occlusion and visibility expressions, and does so both for child and adult speakers of two languages, is unexpected if the *front/back* differences were simply the result of children's early, erroneous analysis of the semantics of two specific prepositions. Together, the results from Experiment 2 support the idea that *front* and *back* make distinct pragmatic contributions that themselves give a relative advantage to *back* in the speech of both children and adults.

As Front scenes did not consistently elicit target information by any age or language group, even at the most inclusive level of spatial encoding, we took a closer look at the types of alternatives used to describe the Front relation. The patterns of use (summarized in Table 7) revealed a range of other prepositions such as *next to* or *beside* (e.g., "The squirrel's ball went right next to the toy," "Pige koda sto pehnidi '(it) went near the toy'"), general goal or source prepositions and/or verbs (e.g., "The ball went away from the toy," "I bala efyge 'the ball left'"), deictics (e.g., "The ball went here/there," "Itan eki ke pige eki '(it) was there and went there'") or trajectory information (e.g., "The ball goes forward," "Ekane mia grammi '(it) did a line'"). These patterns are reminiscent of observations in the literature according to which speakers often use other competing expressions to describe an object's location when not using *front*, with proximity terms (*next to*) and deictic locatives (*there*) being common substitutions, at least for children (see Harris & Strommen, 1979, p. 201; Johnston, 1984, p. 419). (Nontarget uses for Back paths included similar nontarget expressions to Front paths but those were used more sparsely.)

Table 7
Percentage of Spatial Information Types Used for the Front Relation in Experiment 2

Information	English		Greek	
	Children	Adults	Children	Adults
Target				
'front' (in *front of/brosta apo* 'in front of', *from (in) front (of)/ (apo) brosta (apo)* '(from) front (of)')	13	83	7	60
Nontarget				
Other preps or path verbs (*under/kato* 'under', *in the middle of/sti mesi* 'to the middle', *away from/ makria apo* 'away from', *fevgo* 'leave')	73	7	40	40
Deictic (*here/edo* 'here', *there/eki* 'there')	0	0	27	0
Trajectory (*goes forward, does a straight line/ ekane mia grami* '(it) did a line')	13	10	27	0
Total	100	100	100	100

General Discussion

Cross-linguistic research has shown that the acquisition of spatial language follows a consistent—potentially universal—order. However, the precise factors involved in shaping that order have not always been clear. For instance, locative *back* seems to be produced earlier and used more frequently than *front* (Johnston, 1979, 1984; Johnston & Slobin, 1979; Kubena, 1968). This asymmetry has been attributed either to children's incorrect, visibility/occlusion-based semantics for *front* and *back* (*semantic misanalysis* hypothesis) or to pragmatic factors that prioritize the functional correlates of *back* over *front* (*pragmatic inference* hypothesis). Here we set out to explore these two explanations in children and adult speakers of two typologically distinct languages (English and Greek).

In Experiments 1a and 1b, we found that, even though 3- and 4-year-old children, unlike adults, exhibited the *front*/*back* asymmetry in their use of spatial prepositions across languages, no such asymmetry arose in comprehension. Thus, any production advantages for *back* could not be the result of children's incorrect semantics. Furthermore, even though the size of the reference object—and hence whether the figure was fully occluded or not—affected mention of *back* in children's but not adults' production (and did not extend to *front*), just as expected on the semantic misanalysis account, these patterns did not generalize to comprehension, contrary to the predictions of the semantic misanalysis hypothesis. Specifically, in comprehension, children (even though not adults) in both languages were more likely to accept *front/back* when the reference object was bigger than the figure (with the exception of English-speaking 4-year-olds' comprehension of *back* where size did not matter). Because this tendency extended beyond Back configurations, where the size of the reference object affected the visibility of the figure, the role of bigger reference objects is presumably the result of a more general preference for larger-sized objects to serve as anchors for spatial reference (Herskovits, 1985; Landau & Jackendoff, 1993; Talmy, 1983).

In Experiment 2, we found that both children and adults across languages encoded Back paths more systematically compared with Front paths when presented with a diverse array of motion events (even though the difference was larger in children); furthermore, this asymmetry persisted across different levels of linguistic encoding (i.e., prepositions, verbs). This finding is unexpected on an account that treats the *front/back* asymmetry as a transient, developmentally immature stage preceding the acquisition of fully adult-like semantics for the two prepositions.

In sum, our data support the pragmatic inference hypothesis over the semantic misanalysis account of the *front/back* asymmetry. It seems reasonable to assume that child and adult speakers cross-linguistically have a geometric representation of 'front'/'back' terms. On this representation, the semantic meanings of 'front'/'back' terms are symmetrical, as they indicate positions along an orientational axis, but the implied (pragmatic) meanings of these terms (i.e., visibility/occlusion) are asymmetrical. Furthermore, other things being equal, the location or path of an occluded object is more noteworthy compared with the location or path of a visible object. The asymmetrical use of a broader set of expressions implying or encoding occlusion versus visibility across ages and languages in our studies provides additional support to this conclusion.

Our data leave open the possibility that the pragmatic bias to convey occlusion might be motivated by cognitive factors. One intriguing observation in prior literature is that occlusion is associated with high cognitive load: studies comparing predictive reaching for hidden and visible moving objects show that representing hidden objects is harder than representing visible objects for both infants and adults (Hespos, Gredebäck, von Hofsten, & Spelke, 2009; Spelke & von Hofsten, 2001). Furthermore, in these studies, infants and adults had greater difficulty representing objects that were hidden by occlusion compared with objects hidden by darkness, presumably because invisibility attributable to an occluding object distracts attention from the figure, thus creating higher cognitive load. The difficulty of occlusion may in fact be related to the nature of the attentional system. It has been proposed that the organization of object structure is guided by attentional mechanisms: electrophysiological data show that people assign "fronts" to (nonfronted) objects by using the "spotlight" of their attention (Xu & Franconeri, 2012). Hence "backs" of objects should be assigned at a later stage, after the front side has been defined, as the area not receiving the "spotlight" of attention. Once the back side of a reference object has been defined, the figure can be located in the area projected from the back of the reference object. Obviously this process is costlier than identifying objects in the front, which are visible and more easily selected by the attentional system. If representing an occluded object is cognitively demanding, it might be important to mark the configuration linguistically; by contrast, if representing a visible object does not pose any cognitive demands, such configurations might stay unmarked. Thus communicative pressures to mark occlusion may have originated in cognitive factors.

Our study has broader implications for the acquisition of spatial language. In much of the literature, cross-linguistic patterns in the emergence of spatial vocabulary have been considered as a straightforward piece of evidence for the timetable of semantic or conceptual change in children (see Bowerman, 1996; Johnston & Slobin, 1979; see also Huttenlocher et al., 1983 for a similar argument). Even though the role of semantic and cognitive growth in language acquisition is indisputable, the present data suggest an alternative, perhaps complementary, perspective on spatial language learning: on this perspective, children's asymmetrical use of spatial terminology might not always reflect incorrect semantic meanings or immature spatial concepts but rather pragmatic pressures that are also active in more mature (adult) communicators. More strikingly, as our data demonstrate, pragmatic factors determining the choice of a specific lexical item over alternatives can yield cross-linguistically stable patterns of spatial language use in both children and adults. The present approach suggests that detailed comparisons of adult and child usage patterns offer a critical (and often overlooked) piece of evidence in adjudicating between semantic or conceptual and pragmatic explanations of early patterns in spatial language. The current approach also suggests that these comparisons need to examine spatial terminology beyond spatial prepositions and include cross-linguistic evidence from typologically distinct languages (see also Grigoroglou, Johanson, & Papafragou, 2017).

Our approach conforms to a growing body of literature that acknowledges pragmatic contributions to the acquisition and use of spatial language (Levinson & Wilkins, 2006). In one recent study mentioned earlier (Papafragou et al., 2013), children across languages used *out* and *off* infrequently to describe static spatial configurations, even though they used *in* and *on* to refer to canonical containment and support scenes; further experimentation revealed that adults in both the exposure languages and other, unrelated languages also avoided locative *out/off*, reinforcing the conclusion that the restricted use of negative *out/off* was attributable to their pragmatic deficiency. In another demonstration, Papafragou, Massey, and Gleitman (2006) assessed motion event descriptions by children and adult speakers of English and Greek and found that, although the manner of motion is typically not encoded in Greek, the use of manner expressions by Greek speakers increased significantly when manner was not easily inferable from the linguistic or extralinguistic context. In both of these cases, just as in the present data, children's choice of a certain spatial term depended not on the availability of the underlying concepts or spatial semantics but rather on whether the term made an appropriate and specific informational contribution to a spatial description compared with other alternatives (see also Johanson & Papafragou, 2014, for a similar perspective).

These observations cohere with the broader assumption that, cross-linguistically, spatial systems are shaped by general pragmatic principles, such as the need to support informative communication (defined as a measure of how accurately the listener can mentally reconstruct the spatial relation the speaker intended to convey by using a particular spatial term; Khetarpal, Majid, & Regier, 2009; Khetarpal, Neveu, Majid, Michael, & Regier, 2013). Furthermore, cross-linguistic investigations in the semantics of space have shown that the use of a simple description (e.g., "The blue cylinder is on the red cube") typically implies that the located and reference objects are in a stereotypical relation (e.g., the blue cylinder is sitting canonically on the red cube, not teetering on the edge nor with another object intervening between the two), otherwise a less canonical description would have been used (Levinson, 2000; see also Levinson & Wilkins, 2006). The precise way pragmatic considerations interact with conceptual and other factors to affect the acquisition of spatial language is ripe for further exploration.

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