Cross-Disciplinary Advances in Applied Natural Language Processing:

Issues and Approaches

Chutima Boonthum-Denecke
Hampton University, USA

Philip M. McCarthy
University of Memphis, USA

Travis A. Lamkin
University of Memphis, USA

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Chapter 20
Multiple Influences on the Use of English Spatial Prepositions: The Case of "in" and "on"

Michele I. Feist
University of Louisiana at Lafayette, USA

Dedre Gentner
Northwestern University, USA

ABSTRACT

What do people know when they know a word? Previous accounts of the semantics of spatial locatives suggest that spatial meaning is based on both geometric and extra-geometric aspects of spatial scenes. However, attempts to explicitly delineate different sources of extra-geometric influences are still comparatively rare; even more rare are attempts to combine these different sources so as to examine their interactions. This chapter presents four studies examining the ways in which three classes of attributes – geometric, functional, and qualitative physical – influence speakers' uses of the English spatial prepositions in and on. The experiments show that all three kinds of factors play roles in English speakers' choice between these prepositions. The chapter concludes that the semantics of spatial locatives must take into account a complex set of interacting factors.

INTRODUCTION

What does one know when one knows a word? In recent years, substantial attention has been directed at answering this question with respect to spatial locatives (Coventry & Garrod, 2004; Herskovits, 1986; Landau & Jackendoff, 1993; *inter alia*). Spatial locatives have a paradoxical quality. On the one hand, their meanings seem simple and obvious to native speakers. For example, most native English speakers show no doubt as to which term—*in* or *on*—to use to describe the position of the located object (the *Figure*, in Talmy's (1983) terms) with respect to

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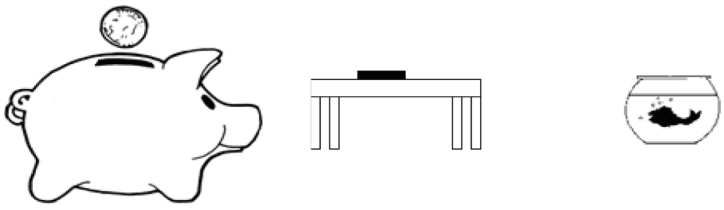
Figure 1. Three spatial scenes and the English, Spanish, and Japanese spatial terms commonly used to describe them



Over	**on**	**in**
sobre	en	en
ue	ue	naka

the reference object (the *Ground*), in each of the pictures in Figure 1. Yet other evidence suggests that these terms are neither simple nor obvious. For example, Dutch and English children do not achieve high production accuracy until about four years of age for the English preposition *on* and its Dutch equivalents (*op*, *aan* and *om*), despite the extremely high frequency of these prepositions (Gentner & Bowerman, 2009). Further, there is marked cross-linguistic variability in how spatial terms map onto the world (e.g., Bowerman, 1996a, 1996b; Bowerman & Choi, 2003; Bowerman & Pederson, 1992, 1996; Choi & Bowerman, 1991; Cienki, 1989; Feist, 2008, 2010; Levinson, 1996; Levinson, Meira, & The Language and Cognition Group, 2003), belying their apparent obviousness. As a case in point, the three-way English distinction presented in Figure 1 corresponds to a two-way distinction in Spanish, and to a separate two-way distinction in Japanese. Specifically, Spanish typically uses a single term (*en*) for scenes typically labeled *on* and *in* in English; while Japanese uses the term *ue* for scenes typically labeled as *over* and *on* in English.

This cross-linguistic variability hints at the astounding complexity of spatial meaning, which is confirmed by the body of research on the semantics of individual terms. However, although spatial locatives have been found to encode both geometric and extra-geometric aspects of spatial scenes, few attempts have been made to separate different sources of extra-geometric factors and test them within the same study. In this chapter, we present a series of studies aimed at assessing the influences of one geometric factor and two different extra-geometric factors – the Ground's function and the qualitative physical interaction of the objects – on English speakers' uses of *in* and *on*.

Geometry

The importance of geometry to the meanings of spatial relational terms has been noted by many researchers (Herskovits, 1986; Landau & Jackendoff, 1993; Regier, 1996; Talmy, 1983, *inter alia*). An approach to the semantics of spatial locatives based purely on geometry is appealing at first glance, given the ease with which spatial locations may be abstracted to geometric form. As a result, many researchers have proposed geometric definitions such as Herskovits' (1986, p. 48) proposed definition of English *in:* "inclusion of a geometric construct in a one-, two-, or three-dimensional geometric construct".

Although geometric descriptions are able to account for many uses of spatial terms, there remain uses that cannot be adequately explained

in purely geometric terms. Consider the definition of *in* given above. While *in* typically describes the location of a Figure at the interior of the Ground, *in* can also be used for situations in which the Figure is not actually at the interior of the Ground: e.g., an apple at the top of a fruit pile can be said to be *in the bowl* even though it lies beyond the bowl's interior (Feist, 2000; Garrod, Ferrier, & Campbell, 1999; Vandeloise, 1991). In addition, in some situations *in* is *not* appropriate, despite the fact that the Figure is at the Ground's interior: e.g., when a pear is at the interior of an overturned bowl (Garrod et al., 1999; Herskovits, 1986). Further complicating matters, there exist configurations that can be described using more than one preposition, as illustrated in (1).

(1) a) The children are *in* the field.
b) The children are *on* the field.

Although there are different shades of meaning for the two sentences in (1), corresponding to separate conceptualizations (Croft & Cruse, 2004), the geometry of the scene remains constant. These kinds of examples are a challenge to purely geometric characterizations of spatial locatives.

Finally, and most problematic for geometric accounts of spatial semantics, there are lexical distinctions that are not at all amenable to a geometric explanation. As a case in point, Bowerman (Bowerman & Pederson, 1992, 1996; Gentner & Bowerman, 2009) reports that Dutch *op* is used for firm adhesion relations, including situations such as a bandaid on a leg, while *aan* is used for instances of hanging (such as a picture on a wall) or tenuous attachment (such as a sticker partly attached to a door). Importantly, these three situations are geometrically equivalent: in each case, a Figure object is in extended vertical contact with the Ground, posing a further challenge to purely geometric characterizations of spatial locatives.

Extra-Geometric Factors

The shortcomings of a purely geometric account of spatial meaning have not gone unnoticed, leading to the proposal that the production and comprehension of spatial terms is influenced by extra-geometric factors, including both the typical function of the Ground (e.g., Carlson-Radvansky, Covey, & Lattanzi, 1999; Coventry, Carmichael, & Garrod, 1994; Vandeloise, 1991, 1994) and the ability of the Ground to control the location of the Figure (e.g., Feist & Gentner, 1997; Garrod, Ferrier, & Campbell, 1999; Richards, Coventry, & Clibbens, 2004).

One index of an object's function is the purpose for which it was created, or its telic role (Pustejovsky, 1991). This has been shown to influence English speakers' use of various kinds of words. In an early demonstration of this phenomenon, Labov (1973) showed that object naming is influenced by functional context. He presented participants with a series of cuplike objects in different contexts (neutral, holding coffee, holding food, holding flowers). When people were asked to name the objects, the noun they chose was influenced by the context in which the object was presented, consistent with the interpretation that the telic role is part of the meaning of the noun used to name the object.

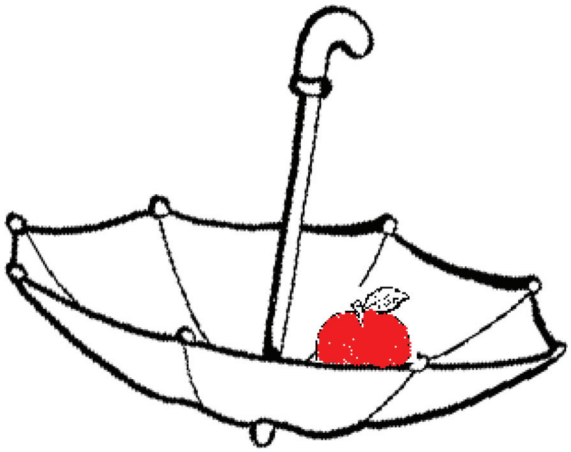
Recent research on spatial semantics has emphasized the importance of the usual function or telic role of the Ground (Carlson-Radvansky, Covey, & Lattanzi, 1999; Coventry, Carmichael, & Garrod 1994) and the resulting functional relation between the Figure and the Ground (Carlson & Kenny, 2006; Carlson, Regier, Lopez, & Corrigan, 2006; Coventry, Carmichael, & Garrod, 1994; Coventry, 1998; Vandeloise, 1991, 1994). For example, Vandeloise (1991, p. 222) makes use of the functional container/contained relation in his definition of the French spatial locative *dans* (which is used for many of the same situations as English *in*): e.g., *dans* applies if the Ground and the Figure are "the first and second elements

in the container/contained relation". Specifically connecting spatial semantics to the fulfillment of the Ground's functional role, Carlson and Kenny (2006) investigated participants' interpretations of *above, below, right,* and *near* and found that they differed according to the identities of the objects, with interpretations tending to respect potential functional interactions between the objects (see also Carlson-Radvansky, Covey, & Lattanzi, 1999).

A second extra-geometric aspect of a spatial relation that may be important to the use of spatial locatives is the qualitative physical (including force-dynamic) relation between the objects (Forbus, 1983, 1984; Talmy, 1988). Specifically, qualitative physics includes information (and inferences) regarding forces exerted by each object to maintain or to change its own location, in addition to forces exerted by one object on the other. Importantly, it includes *locus of control*, or the interpretation that one object has power over the position or location of another (Garrod, Ferrier, & Campbell, 1999; Richards, Coventry, & Clibbens, 2004). The notion of *location control* has been implicated in the meanings of the English prepositions *in* and *on* (Garrod & Sanford, 1989; Garrod *et al*, 1999), as shown in Garrod & Sanford's modification of Herskovits' definition for *in*: " inclusion of a geometric construct in a one-, two- or three-dimensional *functionally controlling* space." (Garrod & Sanford, 1989, p. 155; emphasis added).

Although qualitative physical notions are often included as functional aspects of spatial semantics, we argue here that they constitute a separate aspect of spatial locative meaning. While function deals with intended purpose, qualitative physics includes interactions that are not relevant to the objects' intended purpose, and in fact may vary independently of function. For example, an umbrella was designed to protect its bearer from rain – this is its telic role. In Figure 2, however, the umbrella is serving to constrain the location of an apple. While we normally expect the qualitative physics to correspond to the telic role, this need not be the case.

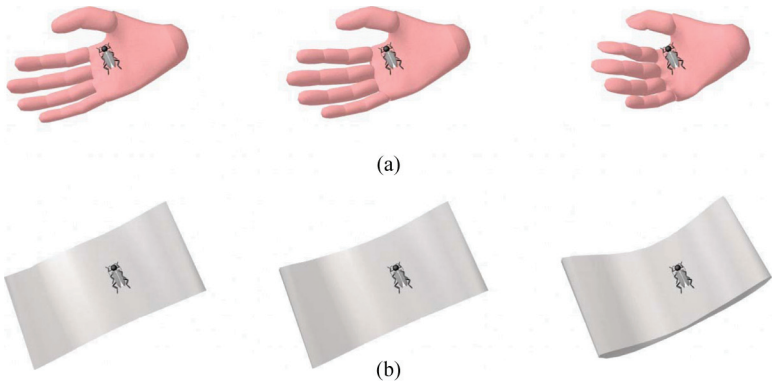
Figure 2. Dissociation of telic role and qualitative physics: an umbrella is constraining the location of an apple



EXPERIMENTS WITH *IN* AND *ON*

In this chapter, we ask whether the geometric and extra-geometric factors discussed above influence the application of English spatial prepositions, using *in* and *on* as our test case. We are interested not only in the factors—geometry, function, and qualitative physics—individually, but also in their interaction. To examine this, we adapted Labov's (1973) classic method for studying complex interacting factors on the use of English nouns such as *cup* and *bowl*. Labov independently varied geometric and functional information, demonstrating that both influence participants' choice of which noun to use for an object. Analogously, we elicited descriptions of simple spatial scenes that lie along an *in/on* continuum and that varied systematically in geometric, functional, and qualitative physical information. Our basic method was to show a simple scene – *e.g.* a hand (varying in concavity) with a coin at its center (see Figure 3) – and ask participants whether the coin was *in* or *on* the hand.

Figure 3. a) Hand paired with firefly at three concavity levels: low (approximately flat), medium, and high (deeply curved); b) Dishlike tray paired with firefly at three concavity levels: low (approximately flat), medium, and high (deeply curved)



Our results suggest that the complexity of spatial terms runs deep, and that their use is influenced by a set of interacting factors.

Geometry

We varied the curvature and concomitant concavity of the Ground to address the question of geometry's influence. Geometrically speaking, *in* is appropriate when the Figure is at the interior of the Ground, while *on* is appropriate if the Figure is in contact with a surface of the Ground. Because variations in the concavity of the Ground change the extent to which it is perceived to have an interior, such variations should affect the use of *in* and *on* to the extent that these terms are sensitive to this geometric distinction. For example, in Figure 3, people should be more likely to use *in* for the high concavity Grounds on the right than for the low concavity grounds on the left if geometric factors are important in preposition selection.

Function

One source of information about the typical function of the Ground is the label applied to it (Labov, 1973; Pustejovsky, 1991). Thus, we varied functional information about the inanimate Ground by introducing it as one of: *dish, plate, bowl*, *slab,* or *rock*. In general, *bowls* function as containers and *plates*, as supporting surfaces. *Dish* is a superordinate of both *bowl* and *plate;* its function should be ambiguous between a container and a supporting surface. In contrast, neither *slab* nor *rock* conveys a functional role: *slabs* are afunctional surfaces and *rocks*, afunctional solids. If the function of the Ground is important in preposition selection, we should find the proportion of *in* responses is highest when the tray is labeled as a *bowl*, lower for *dish*, still lower for *plate*, and lowest of all for *slab* and *rock*.

Locus of Control: Animacy

We examined the possibility that qualitative physical forces might impact preposition use by manipulating the perceived locus of control. We did this by varying the animacy of the Figure and Ground. The consequences of animacy for the perceived locus of control differ depending on whether the animate entity is the Figure or the Ground. An animate Ground can exert volitional control over other objects, including physically restraining them; hence, the Figure is more within the locus of control of an animate Ground than an inanimate one. Similarly, an animate Figure can

exert control over its own position, allowing it to enter or exit a spatial configuration at will and thus making it less susceptible to restraint than an inanimate Figure.

To study the influence of animacy, we included both an animate and an inanimate Ground (a human hand and a dishlike tray) and an animate and an inanimate Figure (a firefly and a coin). By exerting volitional control over the location of the Figure, the animate Ground provides more location control than does the inanimate, raising the applicability of *in*. Thus, if animacy of the Ground is important to prepositional choice, the usage of *in* will be more prevalent for scenes involving the hand than for those involving the dishlike tray.

The influence of the animacy of the Figure is predicted to work in the opposite direction as that of the Ground. If the Figure is able to enter and exit the configuration at will (as can a firefly), it is less subject to external location control than is an inanimate entity (such as a coin), thereby decreasing the applicability of *in*. Thus, if animacy of the Figure is important to prepositional choice, we will find a lower proportion of *in* responses to scenes depicting the firefly than to comparable scenes depicting the coin.

EXPERIMENT 1

Experiment 1 was designed to examine the effects of the geometric, functional, and qualitative physical factors outlined above on English preposition choice.

Method

Participants

91 Northwestern University undergraduates, all fluent speakers of English, received course credit for their participation in this experiment.

Materials

A set of concavity-matched pictures was created using 3D Studio (see Feist & Gentner, 1997; Feist, 2000). These pictures depicted two Grounds (an ambiguous dishlike tray and a hand) paired with two Figures (a firefly and a coin) at three levels of concavity, for a total of twelve pictures. Example stimuli are shown in Figure 3 (above).

Procedure

The pictures were presented in two randomized blocks, each consisting of the entire set of twelve pictures in random order. Each picture was presented for five seconds on a computer screen. Participants were given answer sheets containing sentences of the form:

The *Figure* is IN/ON the *Ground*.

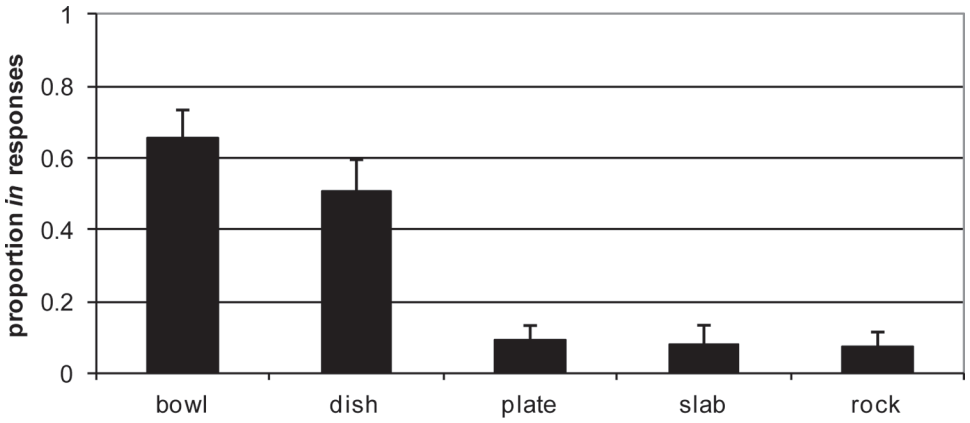
where *Figure* was filled in with the noun referring to the Figure (*firefly* or *coin*), and *Ground* was filled in with *hand* when the animate Ground was shown and the noun corresponding to the labeling condition (*dish, plate, bowl, slab,* or *rock*) when the inanimate Ground was shown.

Participants were told to circle *in* or *on* to make each sentence describe the corresponding picture on the computer screen.

Design

We used a 2 (Ground: hand or dishlike tray) x 2 (Figure: firefly or coin) x 3 (concavity) x 5 (labeling condition) design. Ground, Figure and concavity were varied within subject and labeling condition was varied between subjects: each participant was presented with only one of the five labels for the inanimate Ground.

Figure 4. Results of experiment 1: Proportion in responses to the inanimate ground as a function of the labeling condition, averaged across both figures and all three concavities



Results and Discussion

The results indicate that there were multiple influences on participants' choice between *in* and *on*. A 2 (Ground: hand or dishlike tray) x 2 (Figure: firefly or coin) x 3 (concavity) x 5 (labeling condition) repeated measures ANOVA confirmed main effects of all four factors, as well as some interactions.

As predicted, the proportion of *in* responses increased monotonically with concavity. The proportion of *in* responses for low concavity was .38; medium concavity, .45; and high concavity, .54, $F(2,85) = 21.21$, $p < .0001$.

Also as expected, there was a significant effect of the Ground's label (which conveyed functional information about the Ground) ($F(4,86) = 10.77$, $p < .0001$) and an interaction between the animacy of the Ground and the labeling condition ($F(4,86) = 5.43$, $p = .001$) whereby responses to the inanimate Ground can be seen to drive the effect of the Ground's label (expected due to the fact that the label was only changed for the inanimate Ground). The proportion of *in* responses was highest when the inanimate Ground was referred to as a *bowl*, (a canonical container) ($M = .65$), intermediate for *dish* (M=.50) and low for *plate* (a supporting surface) (M=.09). The proportion of *in* responses was also low when the afunctional labels *rock* and *slab* were used (*slab* $M = .08$; *rock* $M = .07$) (Figure 4).

As predicted, the animate Ground (hand) evoked a higher proportion of *in* responses ($M = .63$) than did the inanimate Ground (the dishlike tray; $M = .28$), $F(1,86) = 65.60$, $p < .0001$. Finally, there was a small but reliable effect of the animacy of the Figure: participants were more likely to choose *in* for the inanimate Figure, *coin* ($M = .49$) than for the animate Figure, *firefly*, ($M = .43$), $F(1, 86) = 9.69$, $p < .005$.

These factors interacted in several ways. First, as already discussed, there was an interaction between the animacy of the Ground and the labeling condition. Second, we found an interaction between animacy of the Figure and labeling condition (Figure 5), $F(4,86) = 2.73$, $p < .05$: the extent to which *coin* received more *in* responses than did *firefly* is greater in the *bowl* and *dish* conditions than in the other three conditions. This difference may arise from the high familiarity of coins being placed in dishes and bowls.

Third, we found an interaction between the animacy of the Ground and its concavity: there was a greater change in the proportion of *in* re-

Figure 5. Results of experiment 1: Proportion in responses as a function of figure and labeling condition, averaged across both grounds and all three concavities

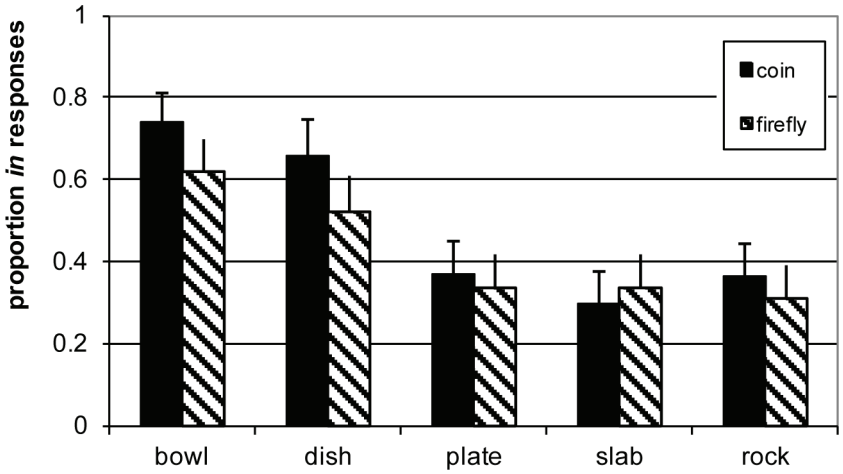
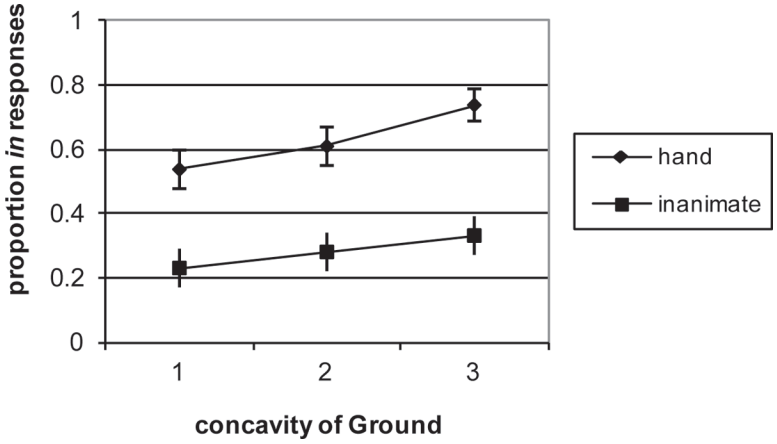


Figure 6. Results of experiment 1: Proportion in responses as a function of concavity and animacy of the ground, averaged across both figures and all five labeling conditions



sponses as a function of concavity for the hand as Ground than for the inanimate Ground (Figure 6), $F(2,85) = 3.86$, $p < .05$. This difference may be due to the relative amount of control that each of the Grounds can exert over the movement of the Figure. Perhaps because it can continue to close, a hand may be conceived of as having more control as it becomes more concave (i.e., more closed), while an inanimate object's amount of control, like its ability to continue closing, would not be conceived of as changing across concavities.[1]

The results of Experiment 1 indicate that all three factors – geometry, function, and qualitative physics – may influence speakers' use of the English spatial prepositions *in* and *on,* both individually and in concert with one another. However, while we would like to conclude that speakers' choice between the English prepositions *in* and *on* is indeed influenced by this set of attributes rather than by any one attribute alone, we must

first further examine the sources of the pattern found in Experiment 1. Therefore, in Experiment 2 we test responses to the pictures and the lexical items separately. The pictures provide geometric and qualitative physical information, but not functional information. In contrast, the sentences provide functional and qualitative physical information, but not geometric information. Experiment 3 continues in this vein, testing the possibility of a purely functional explanation for the pattern of results in Experiment 1. Finally, Experiment 4 provides evidence of the ecological validity of Experiment 1.

EXPERIMENT 2

In order to determine whether participants in Experiment 1 were relying heavily on only one source of information, rather than a combination (as we argue), in Experiment 2 we test each source separately: pictures in Experiment 2a and sentences in Experiment 2b.

Experiment 2a

In Experiment 2a, naïve participants were asked to describe the scenes shown in Experiment 1 in the absence of nouns labeling the Figure and the Ground (by choosing *in* or *on* to complete sentences of the form *A is in / on B)*. The purpose of the experiment was to observe the independent effect of the pictures – and thereby of geometric and qualitative physical information in the absence of functional information – on preposition choice.

Method

Participants

20 Northwestern University undergraduates, all fluent speakers of English, received course credit for their participation in this experiment.

Materials

The stimuli used were the same as in Experiment 1.

Procedure

The procedure was the same as in Experiment 1 except for the following changes: participants were given answer sheets containing sentences of the form

A is IN/ON B.

Participants were told that each of the pictures they would see would depict two objects, and that the smaller object would be referred to as *A* and the larger, as *B*.

Design

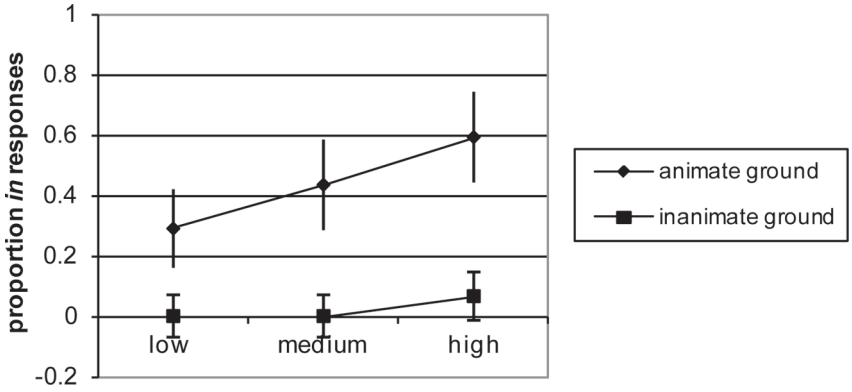
We used a 2 (Ground: hand or dishlike tray) x 2 (Figure: firefly or coin) x 3 (concavity) design. All three variables were varied within-subject.

Results and Discussion

The results replicate the effects of the concavity of the Ground, the animacy of the Ground, and the interaction between the two, suggesting that the use of *in* and *on* is influenced by these aspects of the visual scene. These results were confirmed by a 2 (Ground: hand or dishlike tray) x 2 (Figure: firefly or coin) x 3 (concavity) repeated measures analysis of variance (ANOVA).

As in Experiment 1, the proportion of *in* responses increased monotonically with concavity. The proportion of *in* responses for low concavity was .18; for medium concavity, .25; and for high concavity, .36, $F(2,18) = 6.31$, $p < .01$. Also as in Experiment 1, the animate Ground (hand) evoked a higher proportion of *in* responses ($M = .46$) than did the inanimate Ground (the dishlike tray; $M = .07$), $F(1,19) = 21.62$, $p < .0001$.

Figure 7. Results of experiment 2a: Proportion in responses as a function of concavity and animacy of the ground, averaged across both figures



Finally, we again observed an interaction between the animacy of the Ground and its concavity, in which the effect of concavity was more pronounced for the animate than for the inanimate Ground (Figure 7), F (2,18) = 5.67, $p < .05$. No other significant effects or interactions were found.

Although the proportion of *in* responses was generally lower in Experiment 2a than in Experiment 1, the pattern was very similar. This pattern of results suggests that information gained purely from the visual examination of a scene – including both geometric and qualitative physical information – is used for the selection of an appropriate spatial preposition, reducing the likelihood that the results of Experiment 1 were due solely to information communicated by the lexical items chosen. However, the apparently lower proportion of *in* responses found in this experiment relative to the results of Experiment 1 suggests that information gained from a visual examination of the scenes is not the sole determinant of spatial preposition usage in English. We explore this issue further in Experiment 2b.

Experiment 2b

In Experiment 2b, naïve participants were asked to choose *in* or *on* to complete the sentences presented on the answer sheets in Experiment 1 in the absence of pictures. The purpose was to observe the independent effect of the lexical items referring to the Figure and the Ground – and thereby of some of the functional and qualitative physical information – on preposition choice. Each participant received one of the five labels for the inanimate ground object (*dish, plate, bowl, slab or rock*).

Method

Participants

29 Northwestern University undergraduates, all fluent speakers of English, received course credit for their participation in this experiment.

Materials

Answer sheets containing the following four sentences in random order:

The coin is IN/ON the hand.
The coin is IN/ON the {dish, plate, bowl, slab, rock}.
The firefly is IN/ON the hand.
The firefly is IN/ON the {dish, plate, bowl, slab, rock}.

Figure 8. Results of experiment 2b: Proportion in responses as a function of figure and ground, averaged across all five labeling conditions

Procedure

Participants were asked to circle either *in* or *on* in order to complete each of the four sentences in the most natural-sounding way.

Design

We used a 2 (Ground: hand or dishlike tray) x 2 (Figure: firefly or coin) x 5 (labeling condition) design. Ground and Figure were varied within subject and labeling condition was varied between subjects, with each participant being presented with only one of the five labels for the inanimate Ground.

Results and Discussion

The results bear out the effects of animacy of the Ground and animacy of the Figure, in addition to the Ground by condition interaction, suggesting that the use of *in* and *on* is at least partially influenced by information gleaned from the lexical items. In addition, in the absence of pictures we observed a Ground by Figure interaction. These results were confirmed by a 2 (Ground: hand or dishlike tray) x 2 (Figure: firefly or coin) x 5 (labeling condition) repeated measures analysis of variance (ANOVA). No other significant effects or interactions were found.

The animacy of the Ground influenced participants' responses as in Experiment 1: sentences mentioning the animate Ground (hand) evoked a higher proportion of *in* responses (M = .57) than did sentences mentioning the inanimate Ground (dish, plate, bowl, rock, or slab; M = .28), $F(1,24) = 10.77$, $p < .005$. The animacy of the Figure led to the opposite pattern, as it had in Experiment 1: the proportion of *in* responses when sentences mentioned the *coin* was .62; when sentences mentioned the *firefly*, .22, $F(1,24) = 37.98$, $p < .0001$.

Also as in Experiment 1, the animacy of the Ground interacted with the labeling condition, $F(4,24) = 4.52$, $p < .01$, as again the label was only changed for the inanimate Ground. The use of *in* was highest when the inanimate Ground was referred to as a *bowl* (M = .83), moderately high for *dish* (M = .4), and lowest for *plate* (M = .08), *slab* (M = .08), and *rock* (M = 0), roughly paralleling the pattern found in Experiment 1.

Unlike Experiment 1, Experiment 2b revealed an interaction between the animacy of the Ground and the animacy of the Figure. The use of *in* was dramatically higher for the *coin* than for the *firefly* when the *hand* was the Ground, but less so for the inanimate Ground (Figure

8) ($F(1,24) = 9.85$, $p < .005$). This may be due to the fact that people often hold coins in their hands, leading to a higher lexical association between *coin* and *hand* than between the other Figure-Ground pairs.

The pattern of results obtained in this experiment replicated the relevant pattern of results from Experiment 1, suggesting that information gained purely from the lexical items –both the functional and qualitative physical information – is used for the selection of an appropriate spatial preposition. Additionally, as in Experiment 2a, the actual proportions of *in* responses differed from those observed in Experiment 1, suggesting that the pictures, when available, also exerted influence on participants' preposition choice.

Taken together, the results of Experiments 2a and 2b provide further evidence for the roles of geometric, functional, and qualitative physical factors in the use of English *in* and *on*. As in Experiment 1, the pictures in Experiment 2a varied geometric and qualitative physical information about the Figure and the Ground, while the sentences in Experiment 2b replicated the manipulation of qualitative physical and functional information. Selection of *in* versus *on* was clearly sensitive to both sets of factors.

Experiment 3

Experiment 3 was designed to examine the extent to which the effects found in Experiment 1 may be attributed solely to functional associations derived from the nouns used to label the Ground objects. We asked naïve participants to list functions for each of the functional Ground names used in Experiment 1; due to their afunctional nature, *rock* and *slab* were not examined in this experiment. If the meanings of spatial locatives rely primarily on functional considerations and the English preposition *in* is used when the Ground functions as a container for the Figure (Coventry et al., 1994), one might expect participants to ascribe containment functions to the Ground objects approximately as often as they used *in* with those objects.

Table 1. Example containment functions

Dish	Plate	Bowl	Hand
holds plants	*to hold food*	*to contain something*	*holding things*
to contain meals		*to contain liquid foods*	*basket*

Method

Participants

23 Northwestern University undergraduates received course credit for their participation in this experiment.

Materials

Answer sheets containing six object names: *hand*, either *dish, plate,* or *bowl*, and four distracters.

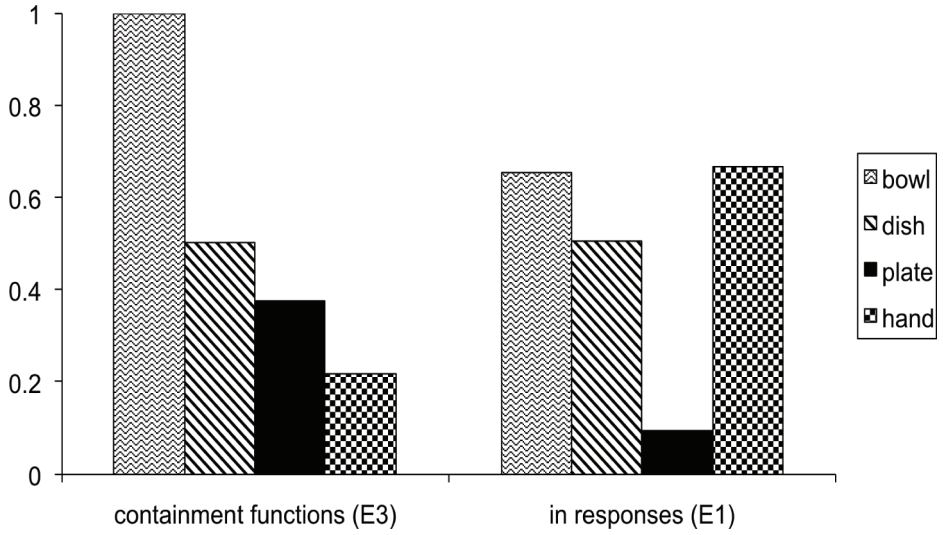
Procedure

Participants were asked to write what they thought of as the functions of each of the items on the sheet. They were allowed to list as many functions as they liked.

Results and Discussion

We coded the functions listed by participants for whether they implied containment, which is functionally associated with *in* (Coventry et al., 1994; Vandeloise, 1991, 1994). Example functions implying containment are listed in Table 1. Because the task was a free response task, we then calculated for each of the nouns the proportion of people who chose to list at least one containment function.

Figure 9. Rate of containment functions listed (Experiment 3) and in responses (Experiment 1) for each of the functional labels



The proportion of people mentioning a containment function for each of the nouns in Experiment 3 shows a different pattern from the proportion of *in* responses to scenes labeled with the same nouns in Experiment 1 (Figure 9). Although the patterns of rate of *in*-usage (Experiment 1) and frequency of containment-listing (Experiment 3) are roughly parallel for the inanimate Grounds, the two measures diverge sharply for *hand*. On both measures, we observed a monotonic decrease from *bowl* to *dish* to *plate*; however, *hand* does not fit into this ordinal series in the same way for both measures. Together with *bowl*, *hand* received the highest rates of use of *in* in Experiment 1, yet it received the lowest rate of listed containment functions in Experiment 3. These results suggest that knowledge about an object's function cannot be solely responsible for the pattern of responses found in Experiment 1.

As a further argument that locatives do not merely reflect functional associations, we note that Green (1971) observed that some sentences involving the preposition *in* cannot be rewritten as sentences involving the verb *contain* without a change of meaning, as shown in the example in (2) (Green's example 4 a-b, p. 198).

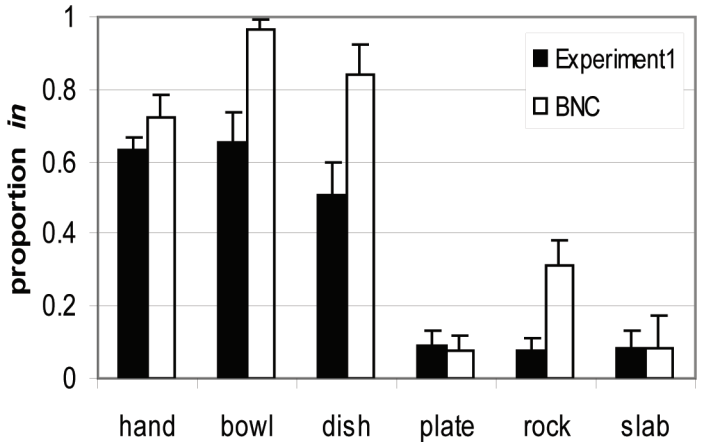
(2) a) His eye has a cinder in it.
≠ b) His eye contains a cinder.

Similarly, although some sentences describing pictures from Experiment 1 could be paraphrased using *contain,* as shown by the pair in (3), others, such as those in example (4), are at best awkward when so paraphrased.

(3) a) The bowl has a coin in it.
= b) The bowl contains a coin.
(4) a) The hand has a firefly in it.
≠ b) The hand contains a firefly.

If the meaning of the English preposition *in* were based primarily on the containment function of the Ground, one would expect that any relation that could be described using *in* would equally well be described using *contain.* The fact that the two are not interchangeable provides additional evidence that the meanings of spatial locatives

Figure 10. Rate of occurrence of in with each of the nouns in experiment 1 and in the British national corpus



involve attributes of spatial scenes in addition to the Ground's telic role or *function.*

Experiment 4

While Experiment 1 presents a snapshot of a set of factors influencing English speakers' preposition choice, if this pattern does not mirror everyday use, the snapshot will be of dubious value. Thus, in this analysis we tested the ecological validity of Experiment 1 by searching the British National Corpus[2] for each of the prepositions used in Experiment 1 (*in* and *on*) in combination with each of the nouns used to name a Ground (*hand, dish, plate, bowl, rock,* and *slab*)[3].

Participants in Experiments 1 and 2b were supplied with nouns and given a forced choice between *in* and *on* to complete each sentence. In order to make the corpus study as similar as possible to the tasks presented in Experiments 1 and 2b, we calculated the relative occurrence of each preposition with each noun. To do this, we collected instances of each noun in combination with each preposition. In order to compare these results with our experimental data, only those uses judged by the experimenter to be clearly spatial were tabulated[4], then the co-occurrence of each noun with *in* was calculated as a proportion of the total number of occurrences of the noun collected.

Overall, the pattern of co-occurrence appears quite similar to the pattern of *in* responses found in Experiment 1 (r = .94), suggesting that our results mirror common usage (Figure 10).

GENERAL DISCUSSION

The results found here suggest that the appropriate use of spatial prepositions in English is influenced by a complex set of interacting geometric, functional, and qualitative physical factors. Specifically, we found evidence that the geometry of the Ground, functional information about the Ground, animacy of the Ground, and animacy of the Figure are all taken into account when choosing an appropriate preposition to apply to a scene. Although each of these factors individually influences the usage of *in* and *on*, none alone is able to fully account for the pattern of usage that we found. This suggests that a descriptively adequate account of the semantics of spatial locatives must incorporate the influences of geometric, functional, and qualitative physical attributes of the scenes being described.

It is not, of course, news that spatial locatives may incorporate both geometric and extra-geometric attributes in their meanings, as outlined in the Introduction. Indeed, there is considerable evidence for the influences of particular geometric, functional, or qualitative physical attributes in the usage of spatial locatives. The role of geometry is supported by Hayward and Tarr's (1995) study, in which the spatial alignment between the Figure and Ground was found to influence the applicability of the English prepositions *over, under, above,* and *below* (see also Coventry, Prat-Sala & Richards, 2001; Logan & Sadler, 1996; Regier & Carlson, 2001). With particular reference to *in*, Garrod et al (1999) found that when the Figure was located at the geometric interior of the Ground, the applicability of *in* was high regardless of other factors which might influence judgments (see also Coventry & Prat-Sala, 2001). In cross-linguistic perspective, Feist (2008, 2010) found evidence that geometric attributes participate in the meanings of spatial locatives across a sample of twenty-four languages.

Object-specific function has similarly been shown to influence English preposition use. For example, Coventry and his colleagues (Coventry *et al*., 1994) found that people were more likely to use *in* when solid Figures (such as apples) were placed with respect to a bowl (which often holds solids) than when they were equivalently placed with respect to a jug (which typically holds liquids). In the same vein, Coventry et al (1994) found that preposition use varied with the label applied to the Ground object, even when the Ground object itself did not change (see also Feist, 2000; Feist & Gentner, 1998). From these two related findings, Coventry and his colleagues conclude that *in* is sensitive to particularities of the function of the Ground, including how that function relates to the specific Figure in question (Coventry & Garrod, 2004). Likewise, Carlson-Radvansky, Covey, & Lattanzi (1999) found that participants take into account the functional relation between the Figure and Ground in the use of *above* and *below* (see also Carlson & Kenny, 2006; Carlson-Radvansky & Radvansky, 1996; Coventry, Prat-Sala & Richards, 2001).

Finally, the qualitative physical attribute *location control* has been found to play a role in the meanings of English spatial prepositions. As a case in point, Garrod et al (1999) found correlations between acceptability ratings for *in* and *on* and predictions regarding the likely change in the Figure's position following removal of the Ground. In a similar vein, the specific nature of the support provided by the Ground (either tight, via adhesion, or loose, via hanging or point-to-point attachment) has been argued to play a role in the difference between the Dutch prepositions *op* and *aan* (Bowerman & Pederson, 1992, 1996; Gentner & Bowerman, 2009; see also Feist, 2008, on the cross-linguistic importance of degree of location control).

This chapter adds to the growing body of evidence for the individual roles of geometry, function, and qualitative physics in the meanings of spatial locatives. At the same time, we up the ante: by examining these three kinds of factors within a single experimental paradigm, we are able to observe their intertwined roles in spatial semantics in addition to strengthening the evidence in support of each factor individually. Further, by explicitly separating functional and qualitative physical attributes in our design, we have shown that extra-geometric aspects of spatial scenes, while frequently reinforcing one another, are separate contributors to spatial locative meanings. Our results show that, rather than being reducible to one or two factors, the use of spatial locatives is sensitive to a complex set of interacting geometric, functional, and qualitative physical attributes of spatial scenes.

Our findings are in line with the observation that the languages of the world encode a variety of different attributes of scenes in their spatial terms (Bowerman, 1996a, 1996b; Bowerman & Pederson, 1992, 1996; Feist, 2008; Levinson, 1996; Majid et al., 2004), including many which

heretofore have not appeared in theories about English spatial semantics. As a case in point, previous studies suggested that the nature of the Figure does not contribute to the use of English spatial prepositions (*e.g.,* Landau & Stecker, 1990). However, research has shown the Figure to play a prominent role in the use of spatial terms in Mayan languages (Brown, 1994; de León, 2000; Levinson, 1996), leading us to the investigation of the role of the Figure reported in this chapter. The effect of the Figure that we found, while quite small, is suggestive of the insights that can be gleaned from broader cross-linguistic work. Just as factors believed to influence the usage of spatial terms in other languages should be tested for their influence in English, factors that have been identified as important to the semantics of English prepositions should be tested empirically for their influence on spatial terms of other languages. By using this paradigm to investigate spatial semantics in many languages, we can further our understanding of cross-linguistic variation and linguistic universals in the semantics of space.

Our results indicate that a broad range of factors enter into the semantics of English spatial prepositions. Their use is influenced not only by the geometry of scenes, but also by multiple extra-geometric factors such as function and qualitative physics, suggesting that spatial meaning may be similarly multidimensional. Underlying the seemingly simple task of localizing objects is a host of subtle factors to which humans naturally and fluently attend. In cataloguing these influences, we come to better understand the human capacity to communicate about the spaces in which we live.

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KEY TERMS AND DEFINITIONS

Figure: The object whose location is at issue.

Ground: Reference object with respect to which the Figure's location is described.

Location Control: Forces exerted on an object that together determine the object's location.

Qualitative Physics: Information regarding forces exerted by or on the objects.

Spatial Locative: A word used to describe the location of one object with respect to another.

Telic Role: The function or purpose for which an object was created.

ENDNOTES

1. We have obtained informal evidence supporting this hypothesis from the comments of children participating in a related experiment.
2. http://www.natcorp.ox.ac.uk/index.html. The British National Corpus consists of over 100 million words of spoken and written modern English.
3. A comparable analysis involving the Figure names was abandoned as *firefly* occurred with neither *in* nor *on* in the British National Corpus.
4. This left a total of 246 occurrences of *hand*, 76 occurrences of *dish*, 134 occurrences of *plate*, 149 occurrences of *bowl*, 156 occurrences of *rock*, and 37 occurrences of *slab*.