Polysemy in Spatially Ambiguous Prepositions

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Cognitive Science Senior Thesis
Polysemy in Spatially Ambiguous Prepositions

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Abstract

Human language strongly connects conveyed ideas to the spatial plane. Prepositions are some of the most important pieces in describing how two entities relate in spatial terms. Yet, within a preposition, there are many different variations in meaning that are conveyed. The word *under*, for example, might refer to a ball sitting *under* a table or a river flowing *under* a bridge, two uses which convey very different spatial and temporal information. In addition to differences in spatial senses, prepositions have metaphoric senses. Again following *under* as an example, a speaker could be *under* pressure. This experiment aims to determine when senses of polysemous prepositions interfere with each other using repeated picture naming procedure in which each prepositional sense had three depictions. We asked three questions: 1) Do distinct spatial senses of prepositions compete? 2) Do antonymic prepositions compete? 3) Do metaphoric and spatial senses of prepositions compete? Based on large gaps in reaction time, it was found that spatial senses interfere with both each other and metaphoric senses. Results regarding opposite pairs, however, was too noisy to give any conclusive indicators of competition. While this data was able to give preliminary ideas of the interference between prepositional senses, it is still unclear the depth and causes of these interactions. Refining the experiment by updating the specific images and number of pictures used, as well as looking more in-depth to variations between prepositional senses, would allow us to further explore the causes and define prepositional sense interference better.
I. INTRODUCTION – PREPOSITIONS AND LITERATURE REVIEW

Human beings are incredibly visual creatures that communicate through phrases wrought with depictions of what is seen. This pictorial terminology dominates over descriptions of sounds, tastes, touches, and smells. Beyond the physical, many colloquialisms across languages include metaphors, like the popular phrase “the mind’s eye” in English, which transpose spatial relationships across non-spatial ideas and are so deeply wound into common use that they activate the sensorimotor cortex, the part of the brain that controls voluntary movements in the body and is thus intrinsically linked to spatial understanding, when processed (Gibbs, 2006, p. 445). Gibbs (2006) claims that this connection is because the understanding of metaphoric language can only be performed by constructing simulations for performing spatial interactions related to that language. This metaphoric language is intrinsically linked to our deep understanding of the space around us.

One of the gears of the English language which allows for such a rich depiction of surrounding space is the preposition, the part of speech which builds a connection between a noun or pronoun and some other element. Other languages have similar linguistic units, like postpositions in Japanese (Kuno, 1996) and spatial noun affixes, which have many similar features to prepositions for describing space (Talmy, 1983, p. 229). For the purposes of this study, we will focus on English and define a word to be a preposition if it fits the part of a preposition in a prepositional phrase, i.e.:

$$PP \rightarrow P \ NP$$

where PP stands for “prepositional phrase,” P stands for “preposition,” and NP stands for “noun phrase” (Hudson, 2000, pp. 106-107). It is important to make this distinction because words which serve as prepositions often act as many other parts of speech, such as an adverb, as well. The Merriam-Webster Dictionary, for example, lists the word *on* as a preposition and an adverb.
One of the adverbial definitions in this case is: “indicating continuation of a movement or action,” as in the sentence “she burbled on.” As a result, for the purposes of this study, it is important to restrict words of interest to prepositional uses. Even with such necessary restrictions, there are countless definitions for just prepositional uses. These several potentially distinct meanings, which are locked under one form and one part of speech, means that prepositions may be polysemous.

What does it mean, exactly, to be polysemous? Xu et al. (2017) examined the manner in which metaphoric mappings evolved and describe the constraints on the semantics of these mappings in order to explain how a traditionally spatial term can come to have metaphoric meaning. Klein & Murphy (2001, 2002) give evidence that, in some cases, there is little semantic overlap between senses of any polysemous word. However, there are multiple types of polysemy, including concrete versus abstract and literal versus metaphoric (Foraker & Murphy, 2012). Specifically, looking at the latter set, in the scope of prepositions, literal polysemy would mean that prepositions have multiple meanings that refer to different spatial relationships, while metaphoric meanings would map some external meaning onto a spatial relationship.

From the understanding of polysemy that Klein & Murphy (2001, 2002), as well as Xu et al. (2017), described, it becomes important to understand how polysemy interacts with our daily language use. One important thing to determine was just how the different senses in a polysemous term are linked to each other. Foraker & Murphy (2012) examined the notion that many types of polysemy have a single dominant sense and several subordinate senses. In this, they found that, under a neutral context, the dominant sense was easier to access (i.e., took less time to name) than any of the subordinate senses. One of the examples given in the study revolves around the word “cotton.” Cotton had a dominant sense of referring to a fabric, which
participants responded to more quickly than they did a subordinate sense of a crop (Foraker & Murphy, 2012). These results, however, depend on how semantically similar the senses are. In the case of prepositions, in which the senses are very semantically similar, this sense dominance may not occur.

In addition to describing polysemy, it is important to address what enables a preposition to convey space. Bierwisch (1999) proposed that our ability to discuss spatial aspects of our environment using linguistic expressions that themselves do not exhibit any sort of spatial structure is due to the symbolic rather than iconic nature of language (p. 31). That is, words are representations whose form is conventionally or arbitrarily associated to objects in our world (Hudson, 2000, p. 4) rather than a sign whose form matches characteristically (i.e., has the same color and shape) of the objects and ideas being conveyed (Hudson, 2000, p. 3). In this understanding, Bierwisch (1999) claims that spatial language can be understood in a few points:

1. Spatial cognition can be considered a representational domain within a conceptual-intentional system that integrates the information from different parts of language (p. 50).

2. These representations of language must be integrated into “propositional representations,” or linguistic statements, where descriptors like the shape, size, and location of objects and the situations in which they are involved will be combined with commonsense knowledge.

Bierwisch thus paints prepositions as parts of speech symbolically depicting the locations of objects. The mind uses other structural points in a sentence alongside commonsense knowledge to build a conceptual understanding of various characteristics of and relationships between these objects. These understandings are, for the most part, spatial descriptors.
Bloom et al. (1999), in contrast to Bierwisch, subscribe to Jerry Fodor’s nativism in their understanding of how prepositions convey spatial concepts. Fodor (1975) proposed that fundamental concepts about the surrounding world, things like color and space, are innately understood in the brain. The means through which we are able to understand these innate concepts is through an “original” innate conceptual apparatus called the “language of thought.” Working out of a framework of the language of thought, Bloom et al. (1999) reference several published neuroscience studies, like those by O’Keefe & Nadel (1978), Shallice (1988), and Taube (1992), to claim that prepositions map onto separated conceptual understandings of spatial representations, and that prepositions gain their descriptive power through this mapping. As a result, they claim that we are able to understand space through our own innate concepts of what space is.

The mechanisms by which prepositions are able to convey spatial ideas, proposed mechanisms being Fodor’s language of thought hypothesis or Bierwisch’s symbolic nature of language, serve as a point of contention between philosophers and linguists. Papers like these, however, convey the importance of prepositions in communicating space. Psychologists have been able to start from whatever mechanistic understanding they prefer in order to determine how the mind treats prepositions. If prepositions are polysemous, then there are many subtleties in how the processing of prepositions would take place. In understanding this polysemy, though, it is important to first define what distinguishes one meaning from another in prepositional space. Linguists debate what exactly constitutes a distinct meaning of a preposition when describing their polysemy. There exist many published theories regarding this boundary, several of which are based on variations of some of the backgrounds studies described above. For the purposes of
In this study, I will examine three influential models exploring prepositional polysemy in order to determine how exactly the mind interprets this intensely spatial part of speech.

II. THE THREE MODELS

There are many conflicting ideas for how the mind distinguishes between different meanings of prepositions. In this study, we examined some of the most unique and influential ideas for the layout of prepositional polysemy. A short review of the three papers we focused on can be found here.

First, Lakoff (1987) proposed a model for addressing prepositions called the radial polysemy model. In a case study on the word “over”, Lakoff describes how each spatial preposition has a large number of entirely distinct polysemous senses that branch out from one basic, central meaning. These radial categories of senses “serve the function of greatly reducing the arbitrariness of correspondences between form and meaning” (Lakoff, 1987, p. 461), meaning that they provide a way to differentiate between various flavors of meaning. By the end of his exploration, Lakoff proposes approximately 47 possibly overlapping but distinct schemas and categories for the word “over.” These senses are based on the surrounding verbal structure, whether or not the use of the word created a mental image or a perception, and how metaphoric or physical the use was. To apply his linguistic model to mental representations and processing, each of these nuanced meanings would be independently tracked and stored. So, if the word “over” is read in a sentence, then the brain would jump to the central meaning and then activate the web of meanings until the one whose semantic and syntactic specifications matched the semantic and syntactic structure of the sentence is selected. Therefore, each meaning would theoretically take a different amount of time to process.
Second, Tyler & Evans (2003) proposed a model of “principled polysemy”, which argues that many of the nodes in Lakoff’s radial semantic network can be combined. They define two criteria for declaring a meaning of a spatial preposition: 1) a meaning that does “not strictly involve spatial relations between physical entities, but rather non-physical concepts associated with… the complex interaction between spatio-physical experience, the human conceptual system, and language use” (Tyler & Evans, 2003, xi), and 2) that there must exist various different senses of the word that have meanings so different that, given another sense of the word, could not be figured out through any means except for the context of the sentence. These two criteria reduce the semantic network of interwebbed meanings to something that will have a smaller, finite number of nodes.

Third, Van Der Gucht et. al (2007) propose a model of spatially-related prepositions that strays away from the path set forward by the previous two models. They challenge the common view of “polysemy” employed by Lakoff, and by Tyler & Evans and claim that this view is based on a faulty Lockean version of semantics. They outline a historical theoretical argument between Locke and Leibniz regarding the interpretation of various meanings of the word “but”, describing how Leibniz defended the idea that all of the different meanings Locke identified the word “but” to possess are merely context-driven variations of one central definition. Following Leibniz’s arguments, the Van Der Gucht, Willems, & De Cuypere model (2007) applies these ideas to the argument against polysemy in spatial prepositions, insisting instead that there is only one meaning or sense for a given preposition. This take on monosemy specifically argues that all of the different senses of the radial and principled polysemy models boil down to different variations of “context dependent uses”, but that all uses are based on one central meaning.
III. PREDICTIONS AND HYPOTHESIS

From the three models described above, I developed an idea on how the mind processes spatial prepositions. Though the monosemy model is appealing, an analysis of claimed senses of various prepositions indicates that there seems to be a continuum of meanings, with one end focusing on purely spatial meanings of the preposition and the other on purely metaphoric meanings. I believe these metaphoric meanings to be independent from spatial ones because, by addressing non-spatial ideas, they cannot be processed the same as a spatial meaning. This important variation in prepositional meaning was ignored by Van Der Gucht et. al in their attempt at defending monosemy, and was never explicitly mentioned by Tyler & Evans or Lakoff in their respective models. As a result, I believe that prepositions cannot be completely monosemous. When metaphoric and spatial senses of a single preposition respectively describe such conceptually and semantically different ideas, there cannot be only one distinct meaning associated with that preposition. Making a distinction between metaphoric and spatial senses opens the door for the possibility that variations in spatial senses constitute different meanings. Indeed, things like a cup being on the table or a Band-Aid being on a papercut conjure up images that represent completely different semantic features. The cup on the table embodies a resting sense of the preposition, which is described by the semantic feature of “support”. The Band-Aid on the papercut, on the other hand, is categorized as a covering sense of the word on. This sense, unlike the cup/table support sense, can be characterized by the semantic feature of “occlusion.” With semantically different features of senses, I am further inclined to believe that there may exist distinct semantic variation in the spatial senses of prepositions, as well. While I think Lakoff went overboard and made his categories too specific, I think he and Tyler & Evans were on the right track.
Based on the above observations, I came up with three hypotheses about the processing of prepositions:

1. There is a difference between the spatial and metaphoric senses of prepositions.
2. There are distinct spatial senses of prepositions.
3. Prepositions which have similar semantic mappings to their senses will compete with each other.

To explore these hypotheses, I employed cumulative semantic interference. This concept is a tool which, in recent years, has emerged in various studies as a useful tool for characterizing underlying relationships between semantic features of names and their related concepts. Most of the work with cumulative semantic interference has revolved around taxonomic relations between nouns. However, I propose that it can be applied here to the relationships between prepositional senses.

IV. CUMULATIVE SEMANTIC INTERFERENCE

The concept of cumulative semantic interference is defined as a linear increase in word production reaction times when various word names retrieved in sequence belong to the same semantic category (Howard et al., 2006). According to some theories, this interference is due to a learning mechanism that strengthens links to selected items (Mensink & Raaijmakers, 1988; MacLeod, Dodd, Sheard, Wilson, & Bibi, 2003), while others claim it suppresses and weakens links to competitors (Anderson et al., 1994; Melton & Irwin, 1940; Postman, Stark, Fraser, 1968).
Let’s assume I have a set of semantic features, for example: has legs, fur, pet, and meows. These four features correspond, with varying levels, to a set of four objects: dog, cat, bird, and fish. Relations are shown in Figure 1, and are as follows:

- Cat has links to all four semantic features
- Dog has links to three semantic features: has legs, fur, pet
- Bird has links to two semantic features: has legs, pet
- Fish has links to one semantic feature: pet

Of course, it is important to note that each of these names have links with many semantic features beyond the four listed above, but for simplicity’s sake, I will only focus on these four names and how those names relate to these four features.

![Figure 1](image_url)

**Figure 1**
Cumulative Semantic Interference network
Blue circles are semantic features, orange circles are object names
The cat is the image being shown to a participant
Now, if I show a participant the picture of the cat, as in Figure 1, and she names it “cat”, the four semantic features that possess links to the word “cat” are strengthened. At the same time, however, the links that each semantic feature has to any of the other three names are weakened. That means, when shown a picture of a dog, bird, or fish, the participant will become slower at naming the animal in the picture at a rate proportional to the number of links shared with the cat image. This means that, with three shared links, the participant will be slowest at naming a “dog”, followed by a “bird” with two shared links, and finally, there will be minimal effect on naming a “fish” with only one shared link. Over time, as well, this effect becomes stronger. If the participant were shown a few completely un-related items followed by a second picture of a cat, the production times for following images of dog, bird, and fish would once again become propositionally slower, and so on and so on for multiple cycles.

To foster a situation where these changes in reaction time would be created, cumulative semantic interference experiments in general follow two paradigms, laid out by Oppenheim et al. (2010) in their influential work. These two paradigms are blocked-cyclic naming and continuous naming. The former (e.g., Damian et al., 2001; Oppenheim, 2018) involves having participants iterate through several cycles of a small set of pictures, where the homogeneity of semantic categories differs by block. The latter (e.g., Brown 1981) involves naming pictures from several semantic categories, where each category has multiple pictures and there is no repetition of particular pictures.
Previous experiments examining the effect of cumulative semantic interference using the blocked-cyclic naming paradigm were performed by Schnur et al. (2009) and modelled by Oppenheim et al. (2010). Graphs from these respective studies are shown in Figure 2. The line labelled “Mixed” represents the baseline for both the model and the experimental data. In this condition, the images shown to the participant are from different semantic categories, and there is therefore no competition. The decrease in reaction time in the Mixed condition is due to learning, and anything that experiences competition will exhibit less of a decrease in reaction time relative to this baseline. This holds true for the block designed to foster cumulative semantic interference, labelled “Homog” for it being a set of images being homogenous, or containing images from the same semantic categories. The delay in production time when items compete for the strength of various semantic features, as described earlier in this section, is evident in this line.

There is debate on whether the interference observed in a blocked-cyclic naming task is due to learning, as is described above by Schnur et al. (2009) and Oppenheim et al. (2010), or if this interference is simply due to the increased difficulty of selecting a name in a homogenous
image set over an unrelated image set. Belke (2017) argues that, depending on the layout of a blocked-cyclic naming experiment, participants pick up on the semantic categories of the block at different times, and depending on how quickly the categorical relatedness of the items in the block is made apparent to the participant affects the data collected from that study. Interference in cyclic naming, therefore, often manifests itself as a stable reaction time form rather than a cumulative form. Regardless of whether or not semantic interference is due to this experimental set-up as described by Belke, or if it is due to the cumulative learning models described by Schnur et al. (2009) and Oppenheim et al. (2010), it will not affect the results of this study. We plan to use semantic interference to determine if there is any processing difference across various contexts, whether or not this also provides insight into the learning behaviors of prepositions.

This debate is important to keep in mind for discussing the results.

**Figure 3**

Graphs from the Oppenheim (2018) paper showing the effect of cumulative semantic interference in a continuous paradigm. As pictures are shown, other objects of similar semantic categories cause the reaction times for related objects to increase through time. Learning applies across both familiar and novel category members.
A recent example from Oppenheim (2018) provides a good example of cumulative interference. Oppenheim performed an experiment that employed the continuous naming paradigm to examine the relationship between different semantic groups. The cumulative semantic interference effects are shown in Figure 3. As opposed to the blocked-cyclic paradigm, which compares reaction times among mixed and homogenous groups, the continuous naming paradigm is characterized by an increase in reaction time relative to a no-change assumption or baseline. Competition is shown by the progressive slowing of the naming of objects over time.

With these understandings of cumulative semantic interference, its paradigms, and the effects of that competition on reaction time better understood, let us get back to our study of prepositions.

V. REFINING THE QUESTIONS

With an understanding of semantic interference, whether cumulative or not, I hope to apply this concept to our hypotheses on prepositions in order to determine whether and where there exist distinct senses of prepositions. Before continuing, an important note with the Oppenheim et al. (2010) and Schnur et al. (2009) experiments is that these results were achieved by presenting participants with images whose focuses contained big conceptual differences – they tested on concepts more similar to cat, dog, bird, etc. than to small variations on the same word. It is unclear if, assuming that distinct senses exist, the variation between those senses is large enough to cause (cumulative) semantic interference in production experiments. While the case could be made that there is enough dissidence in semantic overlap to cause semantic interference, it could also be that the senses are so intrinsically linked that there is no competition at all. Following Klein & Murphy (2001, 2002), there may be no semantic overlap at all,
meaning there would be no competition. However, the work of Klein & Murphy does fit better into the framework of the Van Der Gucht et al. (2007) model. By the Tyler & Evans (2003) model, semantic overlap would exist, meaning there should exist the right amount of competition for cumulative semantic interference, in either of its paradigms and for any of its causes, to work.

I mention this tension because there is the possibility that my suspicions are incorrect, and that senses are not distinct enough to create the cumulative semantic interference effect. However, I propose that this effect will occur with prepositions because the Oppenheim et al. (2010) model is extremely simplified. Unlike the Oppenheim et al. (2010) model, which directly links an object to its semantic features, many learning models include one or more hidden layers between the object and their semantic categories (Elman, 1990; Rogers & McClelland, 2008). A hidden layer provides the power to represent distinct senses of words that can map onto different subsets of the conceptual or perceptual features which characterize that object. Not including these layers makes it so that an object must always exhibit all of the semantic features describing it. Including those hidden layers into a model of concepts that could produce cumulative semantic interference results in something akin to Figure 4 – a mapping of input semantic features (the green circles of semantic features) to various prepositional senses (the blue circles of senses) and, finally, to the output preposition to be produced (the top orange circle).
With these considerations in mind, let us modify the hypotheses into three new questions pertaining to cumulative semantic interference, and let us additionally give predictions for what I expect to find regarding each question.

- Do spatial senses compete with each other?
  - If spatial senses are related (i.e. Tyler & Evans) but not the same (i.e. Van Der Gucht, Willems, & De Cuypere), then I would expect the senses to compete. In this case, the results of a production experiment would produce data similar to that of Schnur et al., as depicted in Figure 2.

- Do prepositions with similar or opposite semantic meanings compete with each other?
  - If prepositions interact with each other semantically similarly to how nouns interact with each other, then we would expect prepositions with similar or opposite semantic features to compete with each other. This will be evident if interference cumulates, but may be difficult to assess if it is constant.

- Is there competition between spatial and metaphoric senses of prepositions? Here, there are two possibilities:
There should not be competition between senses if the spatial and metaphoric senses are distinct. Intermixing metaphoric and spatial senses would reduce the effect of semantic interference.

While I hypothesize that there will not be competition between spatial and metaphoric senses, it is possible that metaphoric senses do interfere with spatial senses because the co-activation of senses still occurs with the naming of metaphoric senses, even if the metaphoric sense does not share features with the spatial sense. See Frazer et al. (2014) for elaboration of this co-activation idea.

VI. THE EXPERIMENT

I designed an experiment using a hybrid of the blocked-cyclic and continuous paradigms for examining cumulative semantic interference. The goal of this decision was to encapsulate the robust measurements achieved through the use of cyclic naming, in which multiple measurements for each word or image are taken, alongside the benefits of having more than one picture per word. This choice helps to handle the fact that senses have so many distinct manifestations, especially when I did not want to pick just one manifestation to use, and to operate around the fact that creating images to represent certain prepositions was more difficult than imagined. Additionally, having multiple pictures representing a single preposition means that we examine a larger space of concepts. Doing so enables the study to measure a wider set of the mappings between prepositions and corresponding pictures. This was crucial because we are not sure if prepositions semantically interact with each other the same way that nouns do, as cumulative semantic interference naming tests have mostly examined nouns. However, we cycled through the set of pictures four times following the blocked-cyclic naming paradigm. We
did this to ensure that we had a large enough set of pictures to run a full array of experiments, to ensure that a wide enough sample of semantic categories were able to interact, and to observe any interference effects from naming the pictures across different conditions. Creating pictures for prepositions is harder than for nouns by their more abstract nature to begin with, and the set of prepositions in the English language is itself smaller than the set of nouns.

The design is summarized in Table 1.

<table>
<thead>
<tr>
<th>Version #1</th>
<th>Version #2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Block 1 - Single Condition</strong></td>
<td><strong>Block 1 - Multiple Condition</strong></td>
</tr>
<tr>
<td>SEMANTIC CATEGORIES: Prepositions of little semantic overlap</td>
<td>SEMANTIC CATEGORIES: Prepositions of little semantic overlap</td>
</tr>
<tr>
<td>NUMBER OF SENSES: Single Sense</td>
<td>NUMBER OF SENSES: Multiple Senses</td>
</tr>
<tr>
<td>SENSE TYPE: Spatial senses only</td>
<td>SENSE TYPE: Spatial senses only</td>
</tr>
<tr>
<td>PREPOSITIONS USED: Behind, In, Near, On, Over</td>
<td>PREPOSITIONS USED: Behind, Below, In, On, Over</td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td><strong>Block 2 - Multiple Condition</strong></td>
<td><strong>Block 2 - Single Condition</strong></td>
</tr>
<tr>
<td>SEMANTIC CATEGORIES: Prepositions of little semantic overlap</td>
<td>SEMANTIC CATEGORIES: Prepositions of little semantic overlap</td>
</tr>
<tr>
<td>NUMBER OF SENSES: Multiple Senses</td>
<td>NUMBER OF SENSES: Single Sense</td>
</tr>
<tr>
<td>SENSE TYPE: Spatial senses only</td>
<td>SENSE TYPE: Spatial senses only</td>
</tr>
<tr>
<td>PREPOSITIONS USED: Behind, Below, In, On, Over</td>
<td>PREPOSITIONS USED: Behind, In, Near, On, Over</td>
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<tr>
<td><strong>Block 3 - Opposites Condition</strong></td>
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<tr>
<td>SENSE TYPE: Spatial senses only</td>
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<td>PREPOSITIONS USED: Over, Under, Up, Down</td>
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<tr>
<td><strong>Block 4 - Metaphoric Condition</strong></td>
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<tr>
<td>NUMBER OF SENSES: Multiple Senses</td>
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</tr>
<tr>
<td>SENSE TYPE: One spatial and one metaphoric sense</td>
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</tr>
<tr>
<td>PREPOSITIONS USED: In, Near, Under</td>
<td></td>
</tr>
</tbody>
</table>

Table 1
Diagram depicting the blocks of the experiment in full detail, and how those conditions vary from each other. Prepositions in italics are used in multiple blocks, and colors are designed to give an indication of comparisons.
There were four experimental blocks. The first two conditions in each version of the experiment together were designed to test the competition of multiple spatial senses of prepositions by examining naming times for prepositions when they appear with one sense per preposition and when they appear with two separate senses. In order to ensure that the order in which these two conditions occurred did not affect the results of the experiment, we ran two versions of the experiment with the order of the single and multiple sense conditions counterbalanced so as to cancel out any effects of ordering.

The single and multiple conditions (1 and 2) are designed to work in collaboration to determine if different senses of spatial prepositions really do compete with each other. The prediction is that there will be more competition in the multiple condition. The opposites condition (3) was designed to test if semantic overlap between prepositions causes competition, similarly to how it does in nouns. There is no baseline in this condition. The prediction is that there exists competition between the two prepositions in each pair of this condition, which will become apparent if there is an accumulation of interference effects in the resulting data. Finally, the metaphoric condition (4) was designed to see if there was competition between spatial and metaphoric senses of prepositions. The prediction is that there will not be competition between the spatial and metaphoric senses in this condition. In turn, these four blocks are designed to work in conjunction, and run by the same participants, to answer the three questions posed by this examination. Additional cross-block comparisons may inform interpretations.
VII. METHOD

Participants

41 undergraduate students at Lehigh University who were native English speakers participated. These students each took about 20-25 minutes to complete the experiment.

Design

The design (summarized in Table 1 above) comprises several subdesigns, each corresponding to one of the three key questions.

1. Subdesign 1 comprises blocks 1 and 2. There are two factors, Number of senses (1, 2) and Cycle (4 levels). Single and multiple senses were presented in separate blocks, counterbalanced between the two versions of the experiment.

2. Subdesign 2 comprises block 3. There are two factors, Preposition meaning (2 levels: opposites of each other) and Cycle (4 levels).

3. Subdesign 3 comprises block 4. There are two factors, Sense type (2 levels: spatial and metaphoric) and Cycle (4 levels).

Materials

The materials used in this experiment were a computer containing the program E-Prime 2.0, microphones, and an audio recorder, and a set of pictures for each block to be shown to the participants. The pictures for each block followed a design based on the number of prepositions involved in the set and how many senses were examined by that set. A constant throughout the experiment was that every sense of a preposition in each block was represented with 3 corresponding images:
1. In the single condition, we examined five prepositions by showing just one spatial sense each. The prepositions chosen were selected to have as little semantic overlap between them as possible. As a result, in this condition, with five prepositions represented by a single spatial sense, and at three pictures per sense, this condition featured a set of 15 pictures (see Figure 5 in the Single vs. Multiple Results subsection).

2. In the multiple condition, we examined five prepositions again, this time showing two spatial senses of each preposition. The prepositions were again chosen to have as little semantic overlap between them as possible. As a result, with five prepositions represented by two spatial senses a piece, and at three pictures per sense, this condition contained a set of 30 pictures (see Figure 6 in the Single vs. Multiple Results subsection).

3. In the opposites condition, we looked at four prepositions with the aim of looking at what happens when there is substantive semantic overlapping. These four prepositions encompassed two pairs of opposites, and each preposition examined a single spatial sense. As a result, at four prepositions of single senses, this condition contained a set of 12 pictures (see Figure 9 in the Opposites Results subsection).

4. In the metaphoric condition, we looked at three prepositions. This time, we showed two senses for each preposition – with one spatial and one metaphoric sense. The prepositions chosen were again selected to have little semantic overlap with each other. As a result, for three prepositions with two separate meanings, this condition contained a set of 18 pictures (see Figure 12 in the Spatial vs. Metaphoric Results subsection).

For sake of clarity, the specific image sets for each condition are not laid out here, but rather are presented in the Materials section for each of the three questions below so that the images can be examined in conjunction with their respective results.
Procedure

Participants were tested individually on a computer equipped with a voice-key and controlled by the program E-Prime 2.0. An audio recorder was used to create a complete recording of each participant’s session for later coding of errors. Participants were first introduced to the experiment set-up. Participants proceeded through four blocks of the experiment, with each block corresponding to a condition (the order of conditions dependent on the version). Each block consisted of two training rounds, during which no data was collected, and a testing phase, during which reaction times were recorded. First, the participants were trained on all the pictures and words in the block. One by one, the participants were presented with a picture from the set and its corresponding preposition. Once the participant said the preposition out loud, the program moved on to the next picture/word pair. The pictures in the set cycled through once. After this training round, the participants went through all the words again in the second training round. This time, however, only the picture was displayed on the screen. Once the participant said aloud what they thought the corresponding preposition was, then the correct word would appear on the screen alongside the picture. All the pictures in the set were cycled through as such once. Then, finally, in the testing phase, all of the pictures were presented for naming with no feedback in four cycles. On each trial, a warning sign and sound appeared, followed immediately by a picture. Participants were asked to name the picture as quickly and accurately as possible. The same procedure was followed for each of the four blocks, with the exception of the last block.

For Block 4, which corresponded to the metaphoric condition, in order to ensure that participants understood the metaphoric pictures they were presented, in the first training round,
participants were asked to say both the preposition and a corresponding sentence describing the picture aloud. Details are provided below.

**VIII. RESULTS, AND DISCUSSION**

Once data was recorded, I was able to go back and code my results for error elimination and data manipulation. Data, which was recorded by E-Prime 2.0 into a .edat file, was exported into a spreadsheet. In the spreadsheet, I extracted the reaction times and corresponding preposition for each trial. Reaction times that were less than 200 ms, and times that were above a $2\sigma$ deviation for the participant were immediately removed. Then, I listened to the audio recording for the corresponding participant’s session and removed the times from any word for which the participant said the incorrect word or for which noise likely triggered the microphone rather than the participant saying the correct word. The reaction times for each participant were compiled into a separate spreadsheet, and manipulated to form the desired results. These results are now presented in this section, divided by each of the three questions in order.

**Single versus Multiple Question**

*Single vs. Multiple Materials*

This analysis compares the reaction times for the single and multiple conditions. The contexts for each were presented in separate, counterbalanced blocks. The images used for the conditions are shown in Figures 5 and 6 below.
Figure 5
Images used for the single sense condition. They are divided by column into prepositions, with three pictures for a single sense of the preposition.
Figure 6

The images used in the multiple condition, divided into column by preposition. The top three images in each column encompass one sense for each preposition. For the four prepositions used in both the single and multiple conditions (behind, in, on, over), the images above the black line are the same ones as in Figure 5. The three images below the black line embody a second spatial sense of each preposition.

Single vs. Multiple Results

In order to comprehensively analyze single versus multiple sense differences, we organized the reaction times from all participants by preposition. Figure 7 contains graphs of reaction times across cycles divided out by sense, placed in separate graphs by each of the four prepositions used in both single and multiple sense conditions. The graphs on the left, the “Total” graphs depict the average reaction time across each cycle for condition one single and multiple sense conditions. The “by Term” graphs on the right depict the same thing, but with the line for the multiple sense data split into its two constituent senses. Finally, Figure 8 contains data for the results of the conditions averaged across all the involved prepositions, including the prepositions not consistent across the two conditions.
Behind - Single vs. Multiple (Total)

Reaction Time (ms)

1 2 3 4

Cycle

Single Sense  Multiple Senses

Behind - Single vs. Multiple (by Term)

Reaction Time (ms)

1 2 3 4

Cycle

"Hiding" - Multiple  "Line" - Multiple

In - Single vs. Multiple (Total)

Reaction Time (ms)

1 2 3 4

Cycle

"Covered" - Multiple

In - Single vs. Multiple (by Term)

Reaction Time (ms)

1 2 3 4

Cycle

"Covered" - Single
Figure 7

All of the data from the single and multiple conditions for each preposition. The graphs on the left average the two senses used in the multiple condition into one line, while the graphs on the right separate the two senses of the multiple condition into two lines. On the right, the two lines of the same color are the same sense and same picture set, but the dashed line is the single condition and the continuous line is the multiple condition.
Across all 8 of the graphs displayed in Figure 7, as well as the averaged graph in Figure 8, the data are highly consistent. While the shape of the exact line differs somewhat between the words, the general trends are the same across all four words. Each of the prepositions had a line for the single condition that fluctuated non-significantly between cycles, where the reaction time in the last cycle was slightly faster than that of the first cycle. The lines for the single sense condition seemed to reflect no cumulative semantic interference as they were flat lines.

However, as discussed in the section regarding Figure 2 earlier in this paper, a flat line possibly reflects a trade-off between practice and interference as learning cancels out competition. This makes the claim that there is no competition along the single sense condition lines ambiguous. Though it is important to note, the ambiguity concerning the existence of competition in the single sense condition line is irrelevant to the contrast between the single and multiple conditions.

**Figure 8**
The data from the single vs. multiple condition, averaged out across all five of the prepositions involved in each condition.
The lines for the multiple condition were similar to the single condition lines in that they were equally consistent, with no major fluctuations. All four prepositions that were held consistent between the two trials, had a final cycle that was about 40 ms faster than the first cycle. Similarly, each preposition showed that the reaction times for the multiple condition were slower than those for the single condition by an average of 53 ms, with individual item differences in a range of 20-84 ms. Examining the reaction times of the multiple condition split into the two tested senses for each preposition, as well, it is interesting to note that the single condition line was always faster than the component of the multiple condition that was the same image set, the same sense (lines always shown in the same light blue color). That is, the exact same pictures used in the single sense condition were named much more slowly when they appeared in the multiple sense condition.

Because of the overall similarity between responses to the two senses in the multiple sense condition, ANOVA tests were conducted only on the overall single vs. multiple contrasts. We conducted a 2 (Number of Senses) by 4 (Cycle) ANOVA on correct response times for each preposition. These results for the single vs. multiple factor are shown in Table 2.

<table>
<thead>
<tr>
<th>PREPOSITION</th>
<th>F(x,y)</th>
<th>p</th>
<th>n2p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Behind</td>
<td>F(1, 39) = 18.02</td>
<td>p &lt; .001</td>
<td>0.316</td>
</tr>
<tr>
<td>In</td>
<td>F(1, 40) = 23.295</td>
<td>p &lt; .001</td>
<td>0.368</td>
</tr>
<tr>
<td>On</td>
<td>F(1, 40) = 14.780</td>
<td>p &lt; .001</td>
<td>0.27</td>
</tr>
<tr>
<td>Over</td>
<td>F(1, 40) = 19.172</td>
<td>p &lt; .001</td>
<td>0.324</td>
</tr>
</tbody>
</table>

Table 2
ANOVA results for the main effect of the single vs. multiple condition, divided out by preposition.

As shown in Table 2, the results obtained are statistically significant and likely not due to any random chance. Cycle was not significant anywhere except for on, F(3,120) = 3.124, p < 0.03. These results are consistent with the patterns we saw in the graphs.
Figure 8 reflects all of the data that each of the individual graphs in Figure 7 depicts, plus the two prepositions that were only used in one condition each. The patterns in this total figure match those from the individual prepositions, and the same pattern of slower reaction times for the multiple sense condition is evident.

The one puzzling part of the data was the strong divergence between the two senses tested in the multiple condition for *in*, as shown in the “In – Single vs. Multiple (by term)” graph in Figure 8. This disparity is likely caused by issues in learning the “surrounded” sense of *in*. Its difference between the first and last cycle reaction times was the most drastic of any of the senses tested in the multiple condition, and looking at the errors made by participants regarded the surrounding sense, not a single participant missed this sense because they said the wrong word. All of the errors instead correlated to the microphones in the set-up picking up sounds outside the scope of the experiment. Participants were just slower with it than with the other sense. The oddness of the data, therefore, can be attributed to a mere learning issue, and its effects are trivial enough that we can still consider the data usable. This feature of the data set, therefore, is not a big concern, and the data for *in* still exhibits the same characteristics between senses as the other prepositions did.

*Single vs. Multiple Discussion*

Looking again at the overall data set, the consistency across the prepositions’ data, coupled with the significant difference in the reaction times between the two conditions, indicates that there exists some difference between spatial senses of prepositions. What exactly that difference constitutes is difficult to determine from the data. Because the shapes of these reaction time lines across cycles echo that described by Belke (2017), it is difficult to say if the
semantic overlap between the senses causes competition in a traditional sense. So then, what might be the cause of this difference in reaction time?

It is conceivable that, because the multiple condition consisted of 30 pictures named 4 times each for 120 naming instances while the single condition consisted of 15 pictures at 60 naming instances, the disparity in block length and number of pictures contributes to the reaction time gap. However, if the images shown in Figures 5 and 6 were valid in their capturing of the conceptual space of the preposition, as we believe they were, then the participants would have latched on to the themes and concepts of the images rather than memorizing the images. In this case, because the participants should have been looking for meaning in the pictures rather than trying to remember them from the training, then the number of pictures in the set should be irrelevant to reaction time.

Additionally, the larger decrease in reaction time shown in the multiple condition over the single condition indicates that the learning period for the task takes longer. If this is due not to the number of pictures in the set, then it means that there is something fundamentally more difficult about naming different senses of a preposition than about naming a single sense of that same preposition. Competition is one likely interpretation of the results of the experiment that could explain these interesting features of the data. Even if competition is not the direct cause, however, the data illustrates that there is something in the mind that causes various senses of prepositions to be interpreted as fundamentally different from each other. While further testing could illuminate the cause and scale of competition, the fact that these results indicate the existence of interference matches our prediction that spatial senses are distinct and should compete with each other.
**Opposites Question**

**Opposites Question Materials**

The images used in the opposites condition are shown in Figure 9. The procedure for this condition ran just as described in the general methods discussion, and there was no difference in this condition between the two versions. In both versions, the opposites condition remained the same and was the third block tested.

![Figure 9](image_url)

The images used in this condition are displayed above. Images are divided by preposition into columns, and each column displays three pictures of the same sense.

**Opposites Question Results**

Similarly to how we divided reaction times by preposition in the single vs. multiple question, in this data set, we divided the data into pairs of opposites in order to compare how prepositions in direct semantic competition were related to each other. Figure 10 shows the data collected for the opposites condition.
The graph on the left shows the results for the up/down competing pair, while the graph on the right shows the results for the over/under competing pair.

**Opposites Question Discussion**

The condition and the question, in turn, were both designed in large part to determine if any semantic overlap between prepositions would result in competition between prepositions. In order to see the magnitude of the effect, if there was to be any, we decided to test the case of largest semantic overlap – opposites. If opposites interfere more than regular prepositions (i.e. in the single condition of the Single versus Multiple Question data) there could be cumulative semantic interference over cycles in this block.

We ran two 2 (words from the opposites) by 4 (Cycles) ANOVA on correct response times for each of the opposites pairs in the data. None of these differences were significant, all Fs < 1.

The results of this condition are therefore inconclusive as to whether or not there exists intensified competition between semantically similar prepositions. The two data sets have very inconsistent patterns, with the up/down graph showing a gap between the two prepositions and
the *over/under* graph exhibiting a cross-over effect. The only seeming pattern between the two graphs is that there seems to be a trade-off in how the opposites behave – in every case, between cycles, when one of the opposite pair increases, the other decreases, and vice versa. However, this trend from Figure 10 was not borne out as being significant from a check using statistics.

Because of the inconclusive nature of the data, it is hard to tell if there is any specific competition between the opposites pairs. Figure 11 shows that the reaction times for *over*, which used the exact same images in both the single condition and the opposites condition, are very similar with little deviation, meaning that any competition variance between the two sets is small. This question remains interesting, but perhaps examining this competition between prepositions was not successful in this small subset of prepositions.

![Figure 11](image_url)

*Figure 11*
Data for the preposition over, using the same set of pictures for the same sense, between both the opposites condition and the single condition.
Spatial versus Metaphoric Question

Spatial vs. Metaphoric Materials

Before delving into this section, it is important to note that for just this section of the experiment, we were only able to use data from 40 of the 41 participants in the study – for one of the participants, there was a computer error in the recording of the data that eliminated data on which sense of a preposition a given reaction time corresponded to. This error occurred only for the metaphoric condition, so the data was usable for the other conditions. However, since the analysis of this section depends on dividing reaction times into senses, we had to eliminate the one participant’s data.

The images used in order to test whether or not metaphoric senses compete with spatial senses are shown in Figure 12. The procedure ran just as described in the general methods section, with the sole exception that, in the first training round, participants read a sentence aloud in addition to the preposition that corresponded to the picture. This was done in order to ensure that the participant understood how a given preposition related to the image that they were shown, so that they could learn the image more easily. In both versions, the metaphoric condition ran as the fourth and final block of the experiment.
Figure 12
The images used in the metaphoric condition. The left two columns correspond to the preposition in, the center two columns to near, and the right two columns to under. In each case, the left column contains the metaphoric terms and the right column is the spatial terms.

Starting from the top left image, progressing down by columns and to the right, the sentences corresponding to the images in Figure 12 are:

<table>
<thead>
<tr>
<th>PREPOSITION</th>
<th>SENSE</th>
<th>SENTENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>In</td>
<td>Metaphoric</td>
<td>They are in love.</td>
</tr>
<tr>
<td>In</td>
<td>Metaphoric</td>
<td>He is in trouble.</td>
</tr>
<tr>
<td>In</td>
<td>Metaphoric</td>
<td>It is in progress.</td>
</tr>
<tr>
<td>In</td>
<td>Spatial</td>
<td>The person is in the house.</td>
</tr>
<tr>
<td>In</td>
<td>Spatial</td>
<td>The book is in the backpack.</td>
</tr>
<tr>
<td>In</td>
<td>Spatial</td>
<td>Schrödinger’s cat is in the box.</td>
</tr>
<tr>
<td>Near</td>
<td>Metaphoric</td>
<td>Washington was near death.</td>
</tr>
<tr>
<td>Near</td>
<td>Metaphoric</td>
<td>We are near the deadline.</td>
</tr>
<tr>
<td>Near</td>
<td>Metaphoric</td>
<td>The process is near completion.</td>
</tr>
<tr>
<td>Near</td>
<td>Spatial</td>
<td>The crow is near the scarecrow.</td>
</tr>
<tr>
<td>Near</td>
<td>Spatial</td>
<td>The lamp post is near the mailbox.</td>
</tr>
<tr>
<td>Near</td>
<td>Spatial</td>
<td>The apple is near the book.</td>
</tr>
<tr>
<td>Under</td>
<td>Metaphoric</td>
<td>He felt under the weather.</td>
</tr>
<tr>
<td>Under</td>
<td>Metaphoric</td>
<td>The speaker was under pressure.</td>
</tr>
<tr>
<td>Under</td>
<td>Metaphoric</td>
<td>The spy was under cover.</td>
</tr>
<tr>
<td>Under</td>
<td>Spatial</td>
<td>The ball sat under the table.</td>
</tr>
<tr>
<td>Under</td>
<td>Spatial</td>
<td>The girl sat under the tree.</td>
</tr>
<tr>
<td>Under</td>
<td>Spatial</td>
<td>The presents are under the Christmas Tree.</td>
</tr>
</tbody>
</table>
Once the pictures and their meanings were understood, using the images from figure 8, the metaphoric condition ran.

**Spatial vs. Metaphoric Results**

For this section, we divided our resulting reaction times into those corresponding to the spatial images and those corresponding to the metaphoric images. Figure 13 shows the results of this examination.

![Figure 13](image)

**Figure 13**

This graph shows the data from the metaphoric condition. The reaction times for each of the three prepositions used in the condition were averaged out into two categories across the four cycles – the spatial sense images and the metaphoric sense images.

We conducted a 2 (Type of sense) by 4 (Cycle) ANOVA on correct response times for the overall average of spatial and metaphoric sense times. There were main effects of both Type of Sense, $F(1,39) = 74.199, p < 0.001$, and Cycle, $F(3,117) = 6.966, p < 0.001$. In addition, there
was a significant interaction between the two factors, $F(3, 117) = 11.816, p < 0.001$. The interaction reflects the clear acceleration of naming in the metaphoric condition relative to the spatial condition.

*Spatial vs. Metaphoric Discussion*

This data, like the single vs. multiple data, displays a large gap between the reaction times of the two conditions. As a result, it can be concluded that there is something fundamentally different between the spatial and metaphoric senses, and that something leads the metaphoric sense to be more difficult to access.

In our predictions, we stated that it was more likely that there would not be competition between spatial and metaphoric senses. It is again difficult to clearly state that this difference is due to competition and interference. In this condition, the spatial sense data acted as a flat line, with there being only an 11 ms difference in reaction time between the fastest cycle (the second at 674ms) and the slowest cycle (the fourth at 663 ms). This flat line shape follows the ambiguity noted by Belke (2017) and is discussed earlier in this study. There could potentially be interference masked in the shape of the data, and it is likely that the spatial sense is easier to access than the metaphoric sense based on the wide gap in reaction times. The metaphoric sense data, on the other hand, witnessed a dramatic decrease in reaction time through the experiment, with times getting faster by at least 20 ms every cycle. There was a 128ms gap between the first, slowest cycle and the last, fastest cycle of this metaphoric line.

The rapid decrease in reaction time exhibited by the metaphoric sense is likely due to learning patterns, especially since the time change between the first and second cycle was so substantial. Participants overwhelmingly commented after they finished the experiment that they
thought the metaphoric condition block was by far the most difficult of any of the conditions they completed. Because of the more abstract nature of the images corresponding to the metaphoric sense, it took longer for participants to associate the prepositions to the corresponding images than for purely spatial senses. As a result, even by the last cycle in the experiment, participants were still likely familiarizing themselves with the metaphoric images. We attempted to reduce the difficulty by having participants read sentences explaining the content of the pictures, as shown in the materials subsection earlier in this paper. However, the effect was just too great to be avoided through two training rounds.

Even without the rapid decrease in reaction time exhibited by the metaphoric condition, there was still a substantial gap in the reaction times between the spatial and metaphoric terms at cycle 4. Here, the metaphoric line was around 60 ms slower than the spatial line. These features indicate quite strongly that metaphoric senses of prepositions are harder to access than spatial prepositions.

Another way to assess the underlying processes in this section of the experiment is to compare the data taken from the spatial images of *in* and *near* to the data taken from *in* and *near* in the single condition – the same set of images was used for both prepositions across the two conditions. This data is shown in Figure 14.

Figure 14 shows that images shown during the single condition are accessed about 60ms faster than the same images shown in the metaphoric condition. This substantial difference in reaction time again indicates that there is something fundamentally different between spatial and metaphoric senses, and when paired together, those senses interfere.

We conducted a 2 (Type of sense) by 4 (Cycle) ANOVA on correct response times for each the in and near data shown in Figure 14. Results showed that the difference between the
single and metaphoric condition was significant. For in, the statistics showed $F(1,39) = 8.842, p = 0.005$. For near, $F(1,39) = 27.306, p < 0.001$.

![Figure 14](image-url)

Data for in and near compared across two conditions – one from the metaphoric condition, looking solely at reaction times for the spatial sense, and one for the single condition. The same images were used for each set of data, so this comparison can be made.

So, do the spatial and metaphoric senses compete? The significant increase in reaction time between senses indicates that the metaphoric sense brings in an element of interference. Additionally, the flat line effects observed in the spatial sense, if following the Belke (2017) logic, could very well indicate interference. While it is difficult to tell what the exact difference between spatial and metaphoric senses is, it is very likely that they do compete, which is the opposite of what we predicted for this study. This may be due to the co-activation effects noted in the predictions section of this study as a counterpoint to our hypothesis that there would be no interference effects in this part of the experiment.
IX. Conclusions and Future Work

The results across all three questions revealed interesting information regarding spatial polysemy. For the first question – the single versus multiple question – it appears that our prediction was substantiated. Due to both the flat line experienced and the wide gap in reaction time between the single and multiple sense conditions on the level of the individual prepositions, it is apparent that interference plays a role in these relationships. There does seem to be a fundamental difference between spatial senses of prepositions, though whether or not dominance plays an effect as it does in nouns remains to be seen. With regard to the second question – the opposites question – our results were inconclusive, both by the shapes of the graphs and by the statistical analysis of the data. Future work concerning antonymic prepositions should therefore be refined in order to attain less noisy data. Finally, the third question – the spatial versus metaphoric question – resulted in the opposite of our hypothesis. Where we expected there to be no competition, there ended up being signs of competition, in the wide gap between reaction times and in the slower responses to the spatial prepositions \textit{in} and \textit{near} in the metaphoric block. There may therefore be co-activation of senses as discussed earlier here, and it may also just be that metaphoric senses are more difficult to access and process than their spatial counterparts. Either way, it does appear that spatial and metaphoric senses interfere.

One of the reasons why it was difficult to tell whether or not the differences between senses of preposition, whether between spatial senses or between a spatial and metaphoric sense, is because we implemented a hybrid of the continuous and cyclic naming tasks. Because we were not able to create a concrete baseline for this task, it was difficult to compare whether or not our flat lined data in the single condition had its shape because of interference balancing out learning. This balance got in the way of determining what the exact causes of the patters we saw
were, resulting in numerous flat lines for the repeated senses in the multiple and metaphoric conditions. Having such interpretation issues is one of the drawbacks of cyclic naming, so using a different task to examine prepositional relations may illuminate different insights regarding the fundamental differences between prepositional senses.

Another way in which to refine the experiment would be to create more pictures for each sense in order to curate a larger set, as well as to include more prepositions so as to further determine the relationship between prepositions. Additionally, since it is arguable that the data results for the single vs multiple conditions was due in part to the disparity in block length, one future change for improving the experiment is to ensure that all blocks include the same number of pictures. Doing so while holding the number of pictures depicting each sense of each preposition constant would require a more complex design. Thought would have to be given to how to execute this change in order to definitively rule out block length as a contributing factor. Finally, including more and different metaphoric senses of prepositions would be vital to refining this experiment. We were limited to lumping all metaphoric senses under one umbrella in order to control this particular study, and it would be interesting to see how metaphoric senses compete, especially between themselves, across the wide spread from close-to-spatial to far-from-spatial mappings. All of these tasks would be made substantially easier using a program that would allow the display of animations, as animations convey senses of motion in a way that is difficult for just static images, as we were limited to in this study.

These goals for future work would further examine polysemy in prepositions by improving the issues with images and by expanding upon relationships between the senses. This study, however, was a good first step into describing how the mind handles this prepositional polysemy.
References


