

The Interpretation of Spatial ‘At’: An Experimental Study*

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This paper presents an experimental study on the interpretation of the spatial preposition *at* in adult speakers, based on a variant of the Truth Value Judgment Task. It is shown that speakers can interpret *at* as denoting a spatial relation that stands in the “lexical entailment” relation with other spatial prepositions (e.g. *inside*, *in front of*, *on top of*, *behind*). For instance, if multiple located entities are involved in this relation, then they may occupy locations that can be “internal”, “external”, or placed on different verses of the same direction, e.g. in front or behind a certain landmark object. It is discussed which semantic hypothesis correctly predicts these findings, and what the implications could be, for a theory of spatial prepositions and their Semantics.

Key words: Spatial prepositions, Semantics, Sentence Processing, Truth Value Judgment Task

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1. Introduction

The interpretation of the spatial preposition *at* has been part of a long and complex debate, in the semantic literature on these parts of speech. Two closely related, yet distinct hypotheses on its meaning can be identified.

The first hypothesis suggests that *at* denotes a certain spatial relation that holds between two entities. This relation holds when a first entity may be located with respect to a second entity, possibly at a relatively close distance. Therefore, the meaning of *at* can include the meaning of other prepositions, although in a restricted way. For instance, in its default interpretation, *at* can include the meaning of *in* or *in front of*. However, whenever a more specific meaning is intended, *at* can receive only this specific meaning. Hence, in a given context, *at* can include the meaning of *in* but not that of *in front of* (Zwarts, 1997; Zwarts & Winter, 2000; Kracht, 2002; a.o.).

The second hypothesis suggests that *at* denotes a spatial relation in which the position of the located entity is not made precise. Therefore, *at* may include the meaning of other spatial prepositions (henceforth: SPs). The intuition is that *at* denotes a situation in which a located entity can be in one of several possible positions. A located entity that is “at” a certain location could actually be located behind this location, or perhaps to either side, inside, and so on. In its lack of spatial precision, *at* is opposed to more “specific” prepositions, such as *in front of*, *on top of*, *inside* or *behind*, among others. These SPs denote the position of the located entity as defined along a given axis, although at different possible distances. Therefore, *at* can include the meaning of several other prepositions, in the same context (Nam, 1995; Levinson & Meira, 2003; Vandeloise, 2005, 2010; a.o.).

As a consequence of their assumptions on the meaning of SPs, these two groups of hypotheses make different predictions about how English speakers interpret sentences such as (1)-(2):

- (1) Luigi is resting at the hotel
- (2) The boys are resting at the hotel

The first hypothesis group predicts that speakers mostly interpret (1) as

denoting a spatial relation in which Luigi is resting somewhere outside, and close to, the Hotel. This hypothesis also predicts that speakers interpret (2) as denoting a shared position for the individuals making up the denotation of *the boys* (e.g. Mario and Luigi). While this position can actually be restricted to one of the more specific meanings included in the denotation of *at*, it is a position that all the relevant boys should share. So, according to this hypothesis the boys in (2) may actually be understood to both be “in” the hotel, but they cannot occupy disjoint positions (e.g. Mario “in”, Luigi “out”).

Instead, the second hypothesis predicts that speakers may interpret (1) in a slightly different way. For instance, speakers may understand that Luigi is resting either inside or outside the hotel. If external positions are entertained, then Luigi may be in front, to the right, or perhaps in any other location defined with respect to the hotel. This hypothesis also predicts that speakers may interpret (2) as denoting a relation in which each of the boys may occupy a distinct, if not “opposed” position. If Mario is in front of the hotel and Luigi behind the hotel, then Mario and Luigi as “the boys” may be located at the hotel.

In other words, *at* can individuate one of several positions that are also associated to the meaning of more “specific” SPs, such as *in front of*. This becomes particularly clear in cases such as (2). In these cases, there can be several located entities whose positions can differ from each other with respect to the ground, and still be labeled as being “at” the ground. Hence, the first and the second group of hypotheses make different assumptions and predictions not only about the interpretation of *at*, but in particular about its semantic relation(s) to other SPs.

We label these two hypotheses as the “Exclusive” and the “Inclusive” hypothesis. Our choice for these labels is based on the following basic intuitions. If *at* parallels other SPs such as *behind* in denoting a specific location defined with respect to a landmark object, then it should be interpreted as denoting an external, possibly adjacent position, distinct from other positions. In other words, the meaning of *at* and *behind* or *in* cannot easily enter in a logical relation; they must “exclude” each other. Conversely, if *at* denotes a non-specific location, then it can also include the meaning of these SPs as part of its own meaning range.

As matters stand, the two hypotheses differ in one key aspect: The Exclusive hypothesis assumes that *all* SPs denote distinct and mutual exclusive types of spatial relations. This assumption implies that the meaning of *at* cannot include the meaning of *inside* and *in front of* in the same context, although it can do so, in independent contexts. Instead, the Inclusive hypothesis assumes that *all* SPs denote spatial relations that may be connected in meaning, as they may be logically connected via the *entailment relation*. In other words, the meaning of *inside* and other SPs can be included in the meaning of *at* in the same context, *at*, as the label “Inclusive” suggests.

This assumption is a natural consequence of the notion of “entailment”, which is defined over the sentences of a language and their interpretation (Landman 1991: ch.1; Kamp et al. 2005: ch. 0; a.o.). The interpretation of two sentences, *S* and *S'*, stands in an entailment relation if and only if the truth of the second sentence *S'* follows from the truth of the first sentence *S*. The entailment relation(s) between sentences that differ only in the SPs they include can be identified with the meaning relation between the two prepositions. So, their entailments can be reduced to *lexical entailment* relations, i.e. entailment relations holding between lexical items. If two sentences stand in an entailment relation and they only differ in their SPs (*P* and *P'*, respectively), then the meanings of the SPs *P* and *P'* stand in a lexical entailment relation (Murphy, 2010; a.o.).

Therefore, the Inclusive hypothesis contends that the meanings of SPs can stand in a lexical entailment relation, while the Exclusive hypothesis seems to restrict this possibility. Hence, the predictive differences of the interpretation of *at* reflect a more general difference on how the semantics of spatial relations, and consequently their semantic relations, are conceived. However, there is surprisingly little evidence on the interpretation of *at* that covers this specific aspect of its meaning (Coventry & Garrod, 2004; Levinson & Meira, 2003; a.o.). Consequently, it is still an open question whether the meaning of *at* can stand in a lexical entailment relation, in distribution and interpretation, with the meaning of other prepositions, such as *inside*. We do not know, yet, whether the Exclusive or the Inclusive hypothesis makes the correct predictions on the interpretation of *at*.

Our goal in this paper is to offer experimental evidence on the spatial

meaning of *at*. Hence, we aim to adjudicate whether the Exclusive or the Inclusive hypothesis correctly predict speakers’ intuitions on the interpretation of this preposition. In doing so, we also have a broader goal, which consists in adjudicating which of the two hypotheses offers an accurate treatment on the semantic interpretation of SPs. If the Exclusive hypothesis correctly predicts speakers’ intuitions, then SPs should denote “partitioned”, exclusive types of spatial relations. The meaning of *at*, as a relation between a locatum and a landmark object, is inherently distinct from the meaning of *behind* or *inside*, among others. However, if the Inclusive hypothesis correctly predicts speakers’ intuitions about *at*, then this preposition has a different semantic status. It should denote a spatial relation that is logically connected, via the entailment relation, to the spatial relations that prepositions such as *in*, *behind* or other SPs denote. Adjudicating this matter, then, has also broader consequences on which hypothesis about the semantic properties of SPs in particular their entailment relations, is correct.

The paper is organized as follows. The remainder of the introduction presents some theoretical background, and a more thorough discussion of the two hypotheses (section 1.1). It then presents a review of some previous experimental studies (section 1.2). Section 2 presents the experiment that adjudicates between the two theories. Section 3 presents some conclusions.

1.1. Theoretical Background

The goal of this section is to present a non-formal but thorough analysis of several proposals about the semantics of SPs, and explain which proposals fall within either the Exclusive or Inclusive hypothesis. We also elucidate the differences in predictions between these hypotheses in detail. Our reason for doing so is that we believe that the differences in predictions among theories can be illustrated precisely, without resorting to formal/logical notation. We will use the labels “entailment” and “lexical entailment” interchangeably, depending on which form better allows us to present an argument. Furthermore, we always assume that the direction of the entailment goes from each more specific spatial preposition (e.g. *in*, *inside*, *on top of*, *behind*, *in front of*) to *at*. So, when we talk about two SPs standing in a lexical entailment relation we mean that, for instance, the truth of a sentence containing the preposition *in* entails the truth of a sentence containing *at*.

We will remind the reader of this assumption when relevant, nevertheless.

It is generally assumed that all SPs denote a spatial relation that holds between a landmark object, or *ground*, and a located entity, or *figure* (Talmy, 1978, 2000).¹ The type of relation that *at* denotes seems to be less specific and more coarse-grained than other English SPs. To see this difference in the level of coarse-grainedness, consider examples (3)-(8):

- (3) Mario is at the public gardens
- (4) The boys are sleeping at the hotel
- (5) The girls are eating lunch at the gelato parlor
- (6) The boys are sleeping in front of the hotel
- (7) The boys are sleeping behind the hotel
- (8) The boys are sleeping inside the hotel

When necessary, we use the theory-neutral label “noun phrase” for syntactic constituents. We follow a standard practice in Discourse Representation Theory (DRT, Kamp and Reyle, 1993; Kamp et al., 2005) and use the label “referent” for the discourse entities denoted by various constituents. In (3)-(5), the noun phrases *Mario*, *the boys* and *the girls* denote certain referents in discourse. These referents are Mario, a salient plurality² of boys, and the girls making up a second, distinct salient plurality, respectively. Their position with respect to the ground referent can be understood in different ways. In (3), Mario is located within the space occupied by the public gardens. In (4), a salient plurality of boys are sleeping somewhere in the surroundings of the Hotel. In such a case, a possibility is that (4) can be understood as describing a scenario in which each boy may possibly occupy a

¹ Since in this paper we focus on the preposition *at* and its semantics, we leave aside a more thorough analysis of *syntactic* properties of prepositions, as they are not crucial to our study. The interested reader is invited to consult Asbury (2008), the works in Cinque & Rizzi (2010); Levinson & Wilkins (2006); for recent advancements on syntactic research about this topic.

² We follow standard approaches to the semantics of plural noun phrases, such as *the boys*, and assume that these noun phrases denote plural referents which include singular referents as their parts (Mario, Luigi and John as parts of the “triad” plural referent). See Link (1998) for a classical reference on this topic.

different position, although the boys as a plural entity are sleeping “at” the hotel. If “the boys” are Mario, Luigi and John, then Mario may be in front of the Hotel, Luigi behind the Hotel, and John on its right.

The same holds for each of the girls in (5), although in this case each girl will be eating lunch, somewhere around the gelato parlor. The prepositions *in front of*, *behind* and *inside* in (6)-(8), instead, denote a more specific type of spatial relation. For instance, *in front of* in (6) denotes a spatial relation in which the salient boys are sleeping in a position which is conceived as frontal, with respect to the hotel. The preposition *behind* in (7) denotes a relation in which the salient boys are in the posterior region, with respect to the hotel. In the case of *inside*, the boys are conceived as occupying the “inner” region of a salient room. Compared to *at*, these prepositions capture more specific spatial relations that hold between figure and ground. Furthermore, in the case of *in front of* and *behind* the occupied region is not a proper, inner part of the ground’s space, unlike in the case of *inside*. However, each of these SPs denotes a specific region involved in this spatial relation, whereas *at* does not necessarily denote a specific region that a figure can occupy.

An open question that emerges, then, is whether or not these spatial relations are logically related via the lexical entailment relation. If (4) and its preposition *at* denote not just one location, but a set of possible locations for the figure, then this sentence may include the interpretation of (6)-(8) as more specific cases. That is, if the boys are sleeping “at” the hotel, then it may be the case that the boys may be actually sleeping in front, or behind the hotel. It may also be the case that each of them is sleeping in a distinct position, so that they could sleep “at” the hotel, although each possibly distributed in a more specific position. Hence, the question at hand is whether the denotation of *at* includes those of *in front of*, *behind* and *inside*. If this is the case, then, the eventual truth of each of the sentences such as (6)-(8) would entail the truth of a sentence such as (4), in the opportune extralinguistic context.

As we foreshadowed in the introduction, the Exclusive and Inclusive hypotheses provide two different answers to this question. To examine why they offer such different answers, we discuss some key works that defend these hypotheses. We start from the Exclusive hypothesis, and we then

move to the Inclusive hypothesis, while also specifying possible sub-types within these hypotheses.

Two related groups of proposals fall under the umbrella of the Exclusive hypothesis. Although these works usually start from different formal (and informal) assumptions, they share the assumption that SPs denote distinct and possibly mutually exclusive types of spatial relations. A first group includes works which offer a “conceptual”, rather than model-theoretic treatment of SPs (Herskovits 1986; Jackendoff 1983, 1990; van der Zee, 2000; Evans, 2010; a.o.). A common thread among these conceptual proposals is that SPs partition the “space” associated to the meaning of SPs into mutually exclusive positions. For instance, these works suggest that *at* denotes a prototypical spatial relation in which the figure is externally located with respect to the ground, in an area that is adjacent to the figure. Although this prototypical relation can include more specific spatial relations in its meaning, its precise interpretation in a given syntactic context restricts its range of interpretations. One consequence is that, if the figure is “at” the ground, then the figure cannot be located “inside” the ground, since the “inside” position is conceived as a distinct location. To see how this hypothesis works, consider examples (9)-(10):

(9) The boy sits at the desk

(10) The girls sit at the bench

In these examples, the possibility that *at* denotes a relation of inclusion between boy/girls and desk/bench, respectively, should be excluded. Desk and bench are grounds that usually cannot “contain” figures within their internal spaces. These works argue that, in specific syntactic contexts such as (9)-(10), *at* cannot denote “inclusive” relations, such as the relations denoted by *in* and *inside*. Therefore, the interpretation of *at* must reflect this “exclusive” restriction to its meaning. Furthermore, the possibility that *at* includes the meaning of SPs such as *in front of* or *behind* is also excluded. These prepositions are assumed to respectively denote relations that do not involve adjacency, and must be restricted to one specific “axial” position. If a given boy is in front of a desk, then it must occupy a frontal, “distal” region with respect to this ground. Overall, the meaning of *at* must be

excluded from being related to (or, more specifically, entailed by) the meaning of other SPs such as *inside* or *in front of*.

A second group consists of works that are within the model-theoretic tradition. One popular approach is known as *Vector Space Semantics* (Zwarts 1997, 2010; Zwarts & Winter 2000; Winter 2006; a.o.). This approach models the spatial relations denoted by prepositions as relations between figure, ground and a third implicit referent. This implicit referent is defined as a *set of vectors*, which are defined as oriented geometrical entities, defined with respect to direction, verse and magnitude, and that connect ground to figure. The verse of a set of vectors is determined by two mutually exclusive relations, which we informally label as “in” and “out”. The relation “in” is defined when the region associated with the figure can be defined as part of the region associated with the ground. The relation “out” is defined when these two regions are mutually disjoint (Zwarts & Winter 2000: 179, corollary 3). Each preposition is then defined as the combination of either relation, plus a relation that defines the direction of the set of vectors with respect to an axis.

An example is as follows. The preposition *in front of* denotes a set of vectors that go from ground to figure, and are aligned with the frontal axis of the ground. Instead, the preposition *at* denotes a set of vectors that go from ground to the external position of the figure, and cover a “short” distance, pragmatically defined. The preposition *in*, on the other hand, denotes a set of vectors that are internally oriented, with respect to the ground (i.e. they point “inside”). Because of this condition of direction and verse, the vectors denoted by *at* cannot include those that are denoted by *in* or *inside*. The key reason for this mutually exclusive relation is that they do not share the same verse, since some vectors point “inside”, while others “outside”.

The relations between *at* and other SPs such as *in front of* are somewhat subtler. Vector Space Semantics defines the relations denoted by SPs such as *in front of* and *behind* as including two properties defined over sets of vectors. However, given the geometrical nature of vectors, the possibility that e.g. *at*, *behind* and *in front of* can stand in an entailment relation is also excluded. Intuitively, the *at* set of vectors connects the figure to the ground when the figure occupies a closer, and non-directed position. The *in front of* and *behind* sets of vectors also connect the figure to the ground. While

both can entail *at* in distinct contexts, they cannot do so in the same context. If we take (4) as a reference, *at* cannot denote a set of vectors which simultaneously connect Mario as being in front of, and Luigi behind the hotel. Such a set of vectors would be “empty”, as it would be defined having opposite verses at the same time. Other proposals differ in the formal details of their treatment, but not in the substance of their claims (Wunderlich, 1991, 1993; Kracht 2002, 2004, 2008; Zwarts 2005; a.o.). Therefore, we do not discuss them in any further detail, in the remainder of the paper.

Overall, these works suggest that *at* denotes an external relation between figure and ground, possibly defined via a set of implicit vectors. These works also exclude that *at* can stand in a lexical entailment relation with other relations, including internal ones such as *inside*. One important consequence of this approach is that the interpretation of sentences involving multiple figures, such as (4)-(8), cannot assign distinct locations to each figure, especially if the vectors that define these locations end up denoting opposite verses and/or directions. Another example to illustrate this point is as follows. Suppose that the noun phrase *the girls* in (5) denotes five girls. If a preposition denotes a set of vectors that must share same direction and verse, then the five girls in the denotation of this sentence must be located in the same position, defined with respect to the gelato parlor. It is not possible that three girls are eating lunch behind the parlor, while two are eating lunch in front of the parlor. In such a case, there would not be a set of vectors with a homogeneous direction and verse, hence no possible interpretation for *at* would be defined.

It is worth noting that Zwarts & Winter (2000: 191-192) suggest that complex coordinated SPs, such as *in front of and below the desk*, may require a different treatment. This treatment would differ in that it would be based on a formal treatment of non-directed regions, rather than on vectors. While this assumption makes the treatment of complex or contrasting locations less problematic, the *at* patterns would still remain, since no account is offered, on how these regions are defined. So, we can safely assume that the model-theoretic side of the Exclusive hypothesis may face problems with these subtle properties of SPs. In this regard, it would also not differ in its range of predictions from the non-model-theoretic side. Consequently, we can also assume that both types of the Exclusive hypothesis run into prob-

lematic predictions, although they start from somewhat different assumptions.

A different scenario is entertained under the Inclusive hypothesis. Works that fall under the Inclusive hypothesis umbrella can also be divided in two groups, similarly partitioned in conceptual and model-theoretic groups. The conceptual sub-type includes a wealth of works, which base their assumptions on various types of data. Examples are psychological findings (Feist, 2000, 2002, 2004; Feist & Gentner 2002, 2003, 2012) and cross-linguistic data (Levinson & Meira, 2003; Levinson & Wilkins, 2006). Some works even include a combination of both data types (Feist 2008, 2009, 2010; Vandeloise, 1994, 2005, 2010).

Nevertheless, all these works observe that speakers generally interpret *at* as denoting a more “complex” type of spatial relation, unless the lexical semantics of the ground blocks certain readings. So, speakers could readily accept that several SPs denoting more specific relations, such as *inside*, *in front of* or *behind*, may form part of the meaning range of *at*. Hence, cases such as (9)-(10) are seen as exceptions to a general rule of meaning relations among prepositions, since these relations can always be accessed in context. The specific meaning of *desk* and *bench* rules out that *at* may include the meaning of *inside* in its interpretation (Vandeloise 2005, 2010). If *at* combines with other types of noun phrases, such as *the garden* or *the Hotel*, then no specific restrictions to its meaning should arise. So, its meaning could logically be entailed by any other spatial preposition.

A second group of proposals that fall within Inclusive hypothesis is instead based on model-theoretic approaches. One such work is Nam (1995), which offers a “mereological” treatment of SPs and the relations they denote. This author suggests that *all* SPs denote a *part-of* relation defined between the *regions* occupied by figure and ground. In the case of *at*, this relation denotes a relation defined between the “extended” space of the ground and the figure. The extended space is defined as the mereological sum of all regions, internal and external alike, that can be defined as topologically connected to the ground. Informally, if we take distinct regions of space, such as the internal, frontal or posterior region (and so on), then their combination into a bigger region defines their mereological sum. So, if a figure is “at” a ground, then the figure’s region is part of the ground’s

extended region. Consequently, if a figure is “at” a ground, then a figure can eventually be “in” the ground, among other positions.

The differences in meaning among SPs are defined as further properties that can individuate a certain “sub-set” of regions. For instance, prepositions such as *in front of* or *behind* denote a relation defined between the figure’s region and a specific region of this extended space. In this case, the specific region is the frontal, external one. A similar approach is defended in previous and subsequent works that take a mereological (algebraic) stance to the Semantics of SPs. Examples include Keenan & Faltz (1985); Bierwisch (1988); Levinson (2000); Ursini (in press); and the discourse-oriented treatment found in DRT (Maillat 2001; Kamp et al. 2005; a.o.). The shared key assumption across these works, conceptual and model-theoretic alike, is that the denotation of *at* be entailed by that of other SPs. This assumption derives from the general semantic properties attributed to SPs, rather than their specific lexical content. Since *at* denotes a “combined” set of regions defined with respect to the ground, it also denotes regions that are in the denotation of more specific SPs.

One logical consequence of this approach is that the lexical entailment relations defined between *at* and other SPs emerge as a logical consequence of their interpretation. That is, *at* denotes a relation between figure and ground that, by definition, includes more specific spatial relations. This holds true in particular when there are multiple figures, as in the case of (4). Although this latter case is more intuitively plausible, it is possible that *at* may also denote “internal” spatial relations and “external” ones, at the same time. If *at* denotes such a complex spatial relation, then it may denote cases in which different, and apparently contrasting specific relations hold as well. In other words, a scenario in which “the boys” are sleeping at the hotel can be a scenario in which Mario is sleeping in front, Luigi behind, and John on the right of the hotel. Therefore, an entailment relation between *inside* and *at*, but also between *in front of* and *at*, and one between *behind* and *at*, can be defined. When one or more than one of these SPs occur in sentences being true in a certain context, then a sentence including *at* is also true, as a logical consequence. Overall, the “inclusive” nature of this mereological treatment to the semantics of spatial relations grants the validity of these entailments as “nested” relations among positions/regions in space.

We summarize our discussion in this section. Since the Exclusive and the Inclusive hypotheses differ in their treatment of SPs, they make different predictions when noun phrases denoting multiple figures are involved. This is a consequence of their different assumption on the interpretation of SPs. In the case of the Exclusive hypothesis, the following prediction holds. If SPs denote “specific” spatial relations, then *at* cannot stand in a simultaneous entailment relation with *in*, *inside*, *in front of* and *behind* (among other prepositions), in a given context. The conceptual sub-type of Exclusive proposals takes this to be the consequence of *at* denoting an inherently different spatial relation than other SPs. The model-theoretic Exclusive proposals, such as Vector Space Semantics, contend that SPs denote sets of vectors, and that each preposition denotes a unique combination of vector-individuating properties.

In the case of the Inclusive hypothesis, instead, the following prediction holds: If SPs denote relations between the locations that figure and ground occupy, then these locations can stand in an inclusive (e.g. part-of) relation. Therefore, *at* can stand in a lexical entailment relation with *in*, *inside*, *in front of* and *behind*, among other SPs. The conceptual variants of the Inclusive hypothesis contend this in less precise way, while the model-theoretic ones derive this assumption from more general, formally explicit assumptions about the semantics of SPs.

This summary concludes our discussion of the Exclusive and Inclusive hypotheses. The next section discusses which theoretical aspects find some experimental validation in the literature, and which are still in need of testing.

1.2. Experimental Background

The goal of this section is to review experimental approaches that have investigated the interpretation of SPs, in particular those works that have investigated meaning relations among SPs. This section also motivates why our empirical question, whether the Exclusive or Inclusive hypothesis correctly accounts the interpretation and entailment relations between *at* and other SPs is still in need of an answer.

Experimental studies on the interpretation of SPs abound, but tend to focus on more specific prepositions such as *in front of* or *on top of*. Several

papers by Coventry and associates present important experiments on this topic (Coventry 1998, 1999, 2003; Coventry et al., 1994; Coventry & Garrod, 2004; Coventry et al., 2009; a.o.). Most, if not all of these experiments were based on *picture-matching* tasks. The experiments were aimed at investigating how English speakers matched pictures that depicted certain spatial relations with sentences that included SPs. The underlying design behind these experiments was simple. Participants had to evaluate pairs of sentences and their ability to match a given picture. The goal was to assess if a preposition was appropriate in a certain extra-linguistic context, and whether different prepositions could be interpreted as “overlapping” in meaning. Participants’ judgments were based on the use of a *Lickert scale* of evaluation, which allowed them to assess to what degree speakers considered two prepositions appropriate, but also overlapping in meaning.

We present the design of one type of experiment in more detail, to make these notions more precise (Coventry & Prat-Sala, 1998, 2001; Coventry et al. 2001, 2009; a.o.). In these experiments, the experimenters showed a picture of a man holding an open umbrella, with the umbrella being located above the man’s head, its handle aligned with the man’s back. The experimenters then asked participants to evaluate whether the sentences exemplified in (11)-(12) correctly described this picture and to what “degree”, if they did find them appropriate:

- (11) The umbrella is above the man
- (12) The umbrella is on top of the man

Participants had to choose a value included in the discrete interval “1-7” for both sentences, with “1” being completely unacceptable and “7” being completely acceptable. Participants showed a strong tendency to consider the sentence in (11) more appropriate, rather than the one in (12). These findings suggest that the preposition *above* more correctly describes the spatial relation in the given picture than the preposition *on top of*. For instance, a paper that studied this specific pair of examples, Coventry et al. (2001), reported a value of mean rating=5.89 for (11), and mean rating=2.27 for (12). So, both SPs adequately described the picture under discussion, although to differing degrees of appropriateness.

Other papers that studied closely related pairs of examples reported similar values. The key aspect is that while speakers clearly prefer sentences which very closely match a given picture, they do not rule out sentences that match these pictures only in part. For instance, participants did not entirely rule out that (12) may still describe the scenario in the aforementioned picture. One explanation offered by the experimenters is the following. A preposition such as *on top of* could be more accurate, if chosen to describe a picture that shows an umbrella literally touching the top of the man's head. In such a case, this preposition captures at least part of the extra-linguistic spatial relation represented in the picture; the umbrella is in a vertical, adjacent position with respect to the man, as the meaning of *on top of* suggests. The meaning of *above*, instead, corresponds to a less specific vertical position, so it is less accurate in experimental contexts that are based on picture-matching tasks.

Overall, these findings suggest that SPs seem to share a core relational component of meaning. This is because they may express part of the extra-linguistic spatial configuration that they purport to represent at a linguistic level. Other works in this line of research offer similar, robust evidence that several SPs can overlap in meaning, in the sense intended by Coventry and Garrod (2004) at least. Examples include: *over*, *in*, *behind*, *on top of*, *on*, *under*, *above*, and several others (Coventry & Garrod, 2004 and references therein). Although these works suggest that an "overlap" relation holds between tested SPs, the results offer evidence that is also relevant to our discussion. For instance, *on top of* denotes a more specific spatial relation than *above*, so we can say that the first spatial preposition entails the second preposition. A similar case can be made, for the most part, for the all the other SPs tested in these works. Therefore, these findings support at least in part the Inclusive hypothesis, since they offer evidence for the relevance of the entailment relation for SPs. The findings seem neutral, instead, for the Exclusive hypothesis' approaches, as they do not explicitly rule out that SPs can overlap in meaning.

Nevertheless, two works offer important evidence on this matter. First, the findings in Coventry & Garrod (2004: ch.4) suggest that *at* can express spatial relations which may be quite "abstract" in nature, to the point of not even being inherently spatial. Consider the examples in (13)-(14):

- (13) The man is at the piano
(14) The man is drinking a beer at the pub

The experiment discussed by Coventry and Garrod found that participants could accept a sentence such as (13) when matched against several pictures, and the scenes they represented. Some cases included a salient man sitting to the left or right side of the piano, behind or in front of the piano. The man could also perform various actions while being located in this position, such as checking the piano, playing some melody, and so on. If (13) was associated to a scenario in which a salient man was performing some action next to the piano, then participants could usually accept this sentence as aptly describing this scenario.

Second, Feist (2006) investigated how speakers interpreted *at* when occurring in sentences such as (14), but also when they produced *at* to describe visual scenarios. The main findings were that speakers could access a more specific meaning for *at* when it was produced, one closer in meaning to the preposition *in*. The less precise interpretation for *at* instead emerged when speakers were asked to interpret a sentence such as (13), and thus were not so sure about its exact, most salient meaning. If speakers could not be sure that the man was actually having a beer inside, rather than outside the pub, then they preferred using *at* to describe this scenario.

As matters stand, then, these findings suggest that *at* stands in a lexical entailment relation with other SPs. When a speaker can accept a more specific preposition, such as *behind*, in a certain context, then the speaker should also accept that *at* can be used in the same context, though it may be less accurate. A direct consequence of this fact is that speakers may accept a sentence including this preposition when it describes several, apparently unrelated scenarios. For this reason, these findings seem to offer support in favor of the following prediction on the interpretation of *at*. If *at* can be accepted in different scenarios that are also acceptable for other SPs, e.g. *inside* or *on top of*, then these SPs are semantically related via the lexical entailment relation. The acceptability of *at* in several extra-linguistic contexts is possible because its denotation includes that of more accurate SPs in context.

However, these findings do not apparently support a stronger claim: that

at may also denote a spatial relation which stands in an entailment relation with several spatial relations "at once". This is a possibility that arises when the relation between figure and ground is actually defined over multiple figures, such as the boys and girls in our (4)-(8) and (10) examples. That is, we still do not know whether *at* can denote a spatial relation which includes the meanings of *in*, *inside*, *in front of*, *on top of* and *behind*, or other SPs' meanings, in the opportune context.

Overall, these findings do not completely adjudicate whether the Exclusive or the Inclusive hypothesis correctly predicts the interpretation of *at* in English speakers. The Exclusive hypothesis is flexible enough to allow that other SPs may entail *at* in the opportune conditions, in particular in the opportune pragmatic (extra-linguistic) context. However, it clearly rules out that *at* can be entailed by *inside*, *in front of*, *behind* or other prepositions which denote different positions of a plurality of referents. More generally, it rules out that *at* may denote several, apparently conflicting, and specific spatial relations, via the entailment relation. Therefore, if we test whether participants can accept *at* in cases in which one or more figures are located in various positions of the ground, then we may obtain two critical pieces of evidence. First, we shed light on whether *at* includes the denotation of more specific SPs as part of its meaning. Second, if this turns out to be the case, then we offer a stronger support in favor of the Inclusive hypothesis, and against the Exclusive hypothesis. We offer this evidence in the next section.

2. The Experiment

The goal of this section is to present an experiment that was performed to adjudicate between the Exclusive and the Inclusive hypothesis, and discuss the empirical import of the findings.

2.1. Participants

The participants were undergraduate students from the authors' Psychology and Linguistics Departments (N=26). All participants were native, monolingual speakers of English. Each participant received course credits for attending the experiment.

2.2. Procedure

The experiment involved a variant of the Truth-Value Judgment Task (TVJ task, Crain & Thornton, 1998). We chose this task for one very simple reason. As we discussed in section 1, the notion of entailment is defined via the notion of truth of a sentence, or the contribution of its constituents to this truth (lexical entailment). Our goal was to test whether the Inclusive or the Exclusive hypothesis can offer a correct account of this lexical entailment relation holding among SPs. Therefore, the use of a task that centers on testing the truth (or falsity) of a sentence in context appears germane to our specific empirical goals.

We shortly explain the choice and structure of a standard TVJ task and its “description mode” type of story, before presenting the variant we used in the experiment. The reason for choosing this task was as follows. The TVJ task offers a simple method to test how participants interpret a sentence in a given scenario. Since the task can involve a yes/no question as a way to elicit a response, it allows one to test which of the two approaches correctly predicts the interpretation of *at*. To anticipate matters a bit, according to the experiment design presented in this section, a “no” answer offers support for the Exclusive approach, while a “yes” answer offers support for the Inclusive approach. The specific procedure that we adopted to elicit these data is defined as follows.

A standard TVJ task involves two experimenters and a participant. The first experimenter presents a short story involving some characters, while the second experimenter controls and acts out a puppet. Before the story is narrated, the puppet is introduced to the participant. The first experimenter explains that the puppet will observe the story with the participant, and will make a statement or a question at the end of the story. The task of the participant is to assess whether the puppet correctly describes the facts in the story or not, hence the name “description mode”.

After this question, the first experimenter offers a follow-up question, aimed at accessing the reason behind the participant’s answer. Stories based on a TVJ task include a condition known as the “Condition of Plausible Dissent” (CPD, Crain & Thornton, 1998; Meroni et al., 2006). This condition states that both possible outcomes of a story must be possible at some

point of the story, so that the target question does not ask a trivially true statement. So, participants may find both a “yes” and “no” answer possible, although only one of them is correct.

An example of a TVJ task that involves a CPD is a story that tested participants’ interpretation of the universal quantifier *every*. In this story, five horses decided to make a competition in which each horse had to jump over a fence, and test who was the best jumper. Each horse attempted the feat, with four of them described as being successful in their task. A fifth horse started his attempt, ran as fast as he could, and when close to the fence he produced a wonderful jump. However, this horse inadvertently tripped into the fence during the jump, so he fell in the small pond below the fence, failing in the task. At the end of the story, the puppet who witnessed the story asked to each participant the question in (15):

(15) Has every horse jumped over the fence?

If participants’ access the interpretation of *every* as that assigned by standard first order logic, then they should offer a “no” answer, as one horse failed to jump over the fence, making the underlying assertion false. In the follow-up question the puppet asks a question such as “why”, or “what happened”. This question tests whether a participant rejected a sentence because some, but not all horses jumped over the fence. If a participant offers such an answer, then the hypothesis that *every* is interpreted as the universal quantifier of First Order Logic seems supported. The Condition of Plausible Dissent is respected, since at some point it is still possible that every horse jumped over the fence. This is roughly a standard form of the TVJ task. The variant of the TVJ task adopted in our experiment featured two main changes, described below.

First, instead of narrating a story and acting out the corresponding scenario in front of the participants, we prepared a powerpoint presentation that performed a similar function. This presentation included slides that showed and described the events of a story aimed at testing the experimental hypothesis. Each slide presented a picture depicting a certain event and characters, with a text that described these events. One experimenter read aloud the story, while the other experimenter distributed consent forms and

answer sheets, and collected the answers (both task and follow-up question) after the experiment.

Second, the puppet was presented in the introduction to the experiment, and appeared at the end of the story to offer the target question. Participants had to write down their answer to the puppet's question on the answer sheet. Afterwards, one experimenter asked a follow-up question, which inquired why participants offered their answer and whether they considered one key character as making the sentence "true" or "false". The exact import of this question will be clear by the next section. Participants could offer an open answer, so that they could explain and defend in detail the reasons behind their choice for the answer.

2.3. Materials

We used the power-point presentation to feature a story in which the main characters were five tank engines from a popular Tv show for children. The toy trains were introduced by name in the story introduction, one engine per slide. The engines were five in total: Thomas, Diesel 10, Spencer, Duncan and Arthur. A sixth character, Mr. Little Bears, was also presented in the introduction as an amnesiac bear who watched the story with the participants. Since he was an amnesiac, Mr. Little Bears would not remember all the events in the story. So, he offered a question to the participants at the end of the story. Before the story began participants received an answer sheet, and once the story finished they were instructed to write down their answer to Mr. Little Bears' question. The use of multiple characters had one goal: If each character occupied a distinct position at the end of the story, then participants should have based their interpretation of *at* as denoting a "complex" spatial relation. This spatial relation should have included different and apparently contrasting positions as part of its intended interpretation, one for each of the involved characters. The specific positions that each character occupied, by the end of the story, are discussed below.

The story had the following structure. The five tank engines had a gruesome day of work. Since they worked hard, they earned a productivity bonus, and could enjoy a night of sleep at the luxury resort "Power Puffs' Hotel". Each tank engine reached the Hotel independently, and was greeted at his arrival by Blossom, the owner of the hotel. Each engine had a short

discussion with Blossom on which location of the hotel was the best for sleeping. Given the hot summer night, Thomas chose to sleep behind the hotel, in the open garden. Duncan initially decided to sleep next to the parking lot, but since he felt a bit cold, he instead decided to sleep inside the hotel, instead. Diesel 10 chose to sleep in front of the Hotel, in the other open garden, and was joined by Arthur at a later time. So, both Arthur and Diesel 10 were sleeping in front of the Hotel. Spencer decided to sleep on top of the hotel’s roof, as he wanted to enjoy the night stars.

Overall, each tank engine slept outside the hotel, except for Duncan, who slept inside. The five tank engines slept in four different positions. Furthermore, while Arthur and Diesel 10 slept in front of the hotel, Thomas slept in the opposite location, behind the hotel. Since Duncan made this decision after initially choosing a different (external) location, the CPD was respected. For each engine, the matching position was explicitly mentioned during the story (e.g. “Arthur is sleeping in front of the hotel”). At some point of the story, the “outside” interpretation of *at* was accessible to participants, since each character that appeared until that point was sleeping outside. However, by the end of the story, the participants should have accessed the “complex” interpretation, since each engine ended up sleeping in a different position. At the end of the story, Mr. Little Bears appeared on a distinct slide and asked the following question to the participants:

- (16) “This is an interesting story! But I do not remember one thing: have all the tank engines slept at the Hotel?”

The use of the universal quantifier *all* had the following goal. A well-known property of universal quantifiers is that, in combination with noun phrases, they force a *distributive* interpretation of the complex predicate it combines with, in this case *slept at the Hotel* (Brisson 1998, 2003; a.o.). Its occurrence in the test sentence, as illustrated in (16), granted that participants evaluated whether each of the five characters was sleeping “at” the Hotel or not. Hence, it tested if participants accepted the entailment relation between *at* and the other SPs: *inside, in front of, on top of, behind*. Participants had to write down their answer on the answer sheet, circling either the “yes” or “no” answer. After making their choice participants were asked a follow-up

question on an individual basis. They were asked the reason why they chose their answer, and whether they considered Duncan as also sleeping “at” the Hotel, as with the other tank engines. The experimenters wrote down each answer on a separate sheet, after collecting the participants’ answers. Below we will review the predictions of the two competing hypotheses, before offering the results of the experiment.

According to the Exclusive hypothesis, participants should have answered “no,” since one engine (Duncan) went to sleep inside the Hotel, and three engines slept in opposing positions (Thomas behind, Arthur and Diesel 10 in front). The two sub-types of this hypothesis substantially make the same prediction, although for different reasons. The conceptual sub-type assumes that *at* cannot denote the position of a figure as being internal to the ground, so it cannot stand in an entailment relation with *in*. The same reasoning holds for *at* and other SPs, as they inherently denote distinct, mutually exclusive meanings. So, Duncan rendered the underlying declarative sentence false and motivated a “no” answer. The model-theoretic sub-type, in particular Vector Space Semantics, also assumes that “opposing” positions are problematic. So, the fact that Thomas slept behind the hotel, while Arthur and Diesel 10 slept in front of the hotel, made a “yes” answer unlikely. The reason for this is that no set of vectors pointing in two opposing verses at one time could be defined, as it would have resulted in the empty set (as discussed in Zwarts & Winter: 191-192). The same reasoning can be extended to the conflict in meaning between *inside* and the external component of other SPs, too.

On the other hand, according to the Inclusive hypothesis, participants should have answered “yes.” This is because the interpretation of *at* can cover cases in which the ground includes the figure. So, Duncan’s position failed to falsify the underlying declarative sentence,³ and motivated a “yes” answer. The same held for all other engines. Furthermore, participants should have defended their answer in the follow-up answer in two complementary ways. They could have pointed out that Duncan was the “offending” engine in the “no” case, or that he was also “at” the Hotel like the other

³ We thank an anonymous reviewer for suggesting to us this more accurate way to state our predictions.

engines in the “yes” case. As in the Exclusive case, the two sub-types of the hypothesis make the same prediction via slightly different assumptions. The conceptual sub-type contends that *at* can include the meaning of one or more other SPs in context. Instead, the model-theoretical or mereological sub-type contends the fact that SPs share an underlying part-of relation as their core meaning. Hence, prepositions can and should be related via the lexical entailment relation. Therefore, the aforementioned predictions should hold: speakers should accept the entailment relation between *at* and *in*, *at* and *in front of* (and so on).

2.4. Results and Discussion

The results were as follows: 25 participants answered “yes”, while one participant answered “no”. In a total of 26 participants, the “yes” percentage was 95.6%, the “no” percentage was 4.4%. If we assume a confidence interval of 5% (i.e. that 5% of the participants could have answered by chance), then the results seem to support the Inclusive hypothesis, rather than the Exclusive one. Under this assumption, we would expect a 95% percent of “yes” answers according to the Inclusive hypothesis. Consequently, no statistically significant divergence was found. The reverse holds true for the Exclusive hypothesis, as well.

The follow-up answers offer similar evidence. When asked whether one “offending” tank engine, Duncan, was also sleeping “at” the Hotel, rather than in some other location (e.g. “inside”), participants offered the following answers. 25 participants who answered “yes” defended their answer by pointing out that Duncan occupied a region of the Hotel, like every other engine. The single participant who answered “no” defended this choice by pointing out that, apparently, only one engine was really “at” the Hotel, while other engines were sleeping at a relatively far distance from the hotel. To an extent, this participant considered the meaning of *at* closer to that of *inside*, than to that of *in front of*, *on top of* or *behind*. Furthermore, no participant found problematic that Arthur and Diesel 10 were sleeping on the “opposing” side of Thomas, with respect to the Hotel. These findings are consistent with the Inclusive hypothesis, but not with the Exclusive hypothesis.

Overall, these answers further corroborate the suggestion that the

Inclusive hypothesis correctly predicts the interpretation of *at*, while the Exclusive hypothesis seems to be in need of revision. Participants had no trouble in accepting Duncan's position as being "at" the Hotel, as they also confirmed via the follow-up question. This datum is unexpected under the Exclusive hypothesis, especially if one considers that the lone "no" participant considered the scenario not accurate enough, to an extent. This datum, instead, is one key piece of evidence for the Inclusive hypothesis, as this hypothesis predicts precisely this type of answer.

Another datum in favor of the Inclusive hypothesis pertains to the position of Arthur, Diesel 10, and Thomas. While Arthur and Diesel 10 slept in front of the Hotel, Thomas slept behind the hotel. It is useful to review why this datum is problematic for the External hypothesis. According to the formal approaches within the Exclusive hypothesis, such as Vector Space Semantics, the definition of a "common" position that holds for each of these three engines is far from trivial. If we think of SPs as denoting sets of vectors, *then in front of* and *behind* denote two sets of vectors with opposite verse. As in the case of *at* and *inside*, it should not be possible to define a set of vectors that includes both sub-sets.

So, our results offer two pieces of evidence that challenge the Exclusive hypothesis, and its assumption that the meanings of SPs can be mutually exclusive, hence quite restricted in their logical connections. Conversely, these results also offer two pieces of evidence that the Inclusive hypothesis makes the correct predictions about the meaning of *at* and its entailment relations with other SPs. Speakers readily accepted that *at* could describe a scenario that included "smaller" scenarios described by *inside*, *in front of*, *on top of* and *behind*. Therefore, they readily accessed the meanings of these SPs as connected via the lexical entailment relation, a logical consequence of the underlying mereological semantics of these words. This result is in line with previous findings, as we discussed in the previous section.

3. Conclusions

In this paper we have offered experimental evidence that the English spatial preposition *at* denotes a complex spatial relation, which holds when one or more figures may occupy several possible locations. Given this assumption,

at turns out to stand in a lexical entailment relation with other SPs, such as *outside* and *inside*, as well as *in front of*, *on top of* and *behind*. More precisely, the interpretation of each of these more specific SPs can lexically entail the interpretation of *at*, since *at* seems to denote the “sum” of more specific SPs. These findings suggest that several proposals falling under the Exclusive hypothesis group are incorrect, as they predict that *at* cannot denote such a sum of different SPs, if their meanings are mutually exclusive. Conversely, these findings support those proposals that fall under the Inclusive hypothesis group. They support proposals which consider *at* as denoting an somewhat more abstract, hyperonym-like relation with respect to the hyponym-like relations denoted by *inside*, *in front of*, *on top of*, or *behind*, and possibly several others.

The general conclusion is that our findings suggest that SPs do *not* denote mutually exclusive spatial relations, but that they are logically connected via the lexical entailment relation. If *at* denotes a spatial relation that corresponds to the “sum” of more specific spatial relations, then it will include more specific relations, denoted by SPs such as *inside* or *behind*, as part of its denotation. So, the truth of a sentence including *at* will be granted by the truth of several sentences including related SPs. In other words, these findings support the view that, in the right context, these SPs can entail the preposition *at*. Overall, we believe that our findings support the claim that a more accurate and “structured” approach to the Semantics of SPs is called for. If SPs are related via fine-grained lexical entailment relations because of their core relational semantics, then one needs a semantic theory that can correctly capture these relations. The Inclusive hypothesis, in particular the mereological sub-type, seems to offer a formally explicit theory that captures and predicts these facts. For this reason, it seems a more accurate hypothesis about the meaning of *at*, and its logical relation with the other SPs we tested in this paper, than the Exclusive hypothesis.

These answers about the interpretation of *at*, and more generally about the semantic properties of SPs, leave open at least three more questions. One question is whether a condition on distance plays a role in the meaning of *at*. In our experiment, we did not attempt to place the tank engines at distances that could be labeled as being “far” or “near”, from the Hotel. So, we do not know whether *at* denotes what we could call a “General Spatial

Term” (Feist, 2004, 2008), i.e. not restricted by the locations it denotes, and their relative distances. A second question is whether the lexical properties of *at*, to stand in an entailment relation with other SPs within the same linguistic and extra-linguistic context, can be extended to other cases as well. For instance, in our experiment we tested whether participants accepted that Spencer was sleeping “at” the Hotel, since he was sleeping *on top of* the Hotel. We do not know whether participants would have accepted this sentence if another tank engine was sleeping below (or under) the Hotel, somehow. Although we can speculate that this other case of complementary locations would be unproblematic, we still are in need of an empirical validation. A third question is whether these findings hold cross-linguistically. The cross-linguistic existence of a preposition that covers the meaning range of *at*, and its ability to be involved in entailment relations with other SPs, has been amply documented. Examples include Korean’s case marker *-ey* (Lee, 2012), German *an* with dative-marked ground NPs (Bierwisch, 1988), Italian *a* (Rizzi, 1988), and Spanish *en* (Zwarts, 2010). Other examples are also amply documented in the literature (Levinson & Meira, 2003; Vandeloise, 2010; a.o.). Of course, other questions could be further formulated. However, we leave the task of finding the answers to these questions for future research.

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