On the role of informativeness in spatial language comprehension

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by

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Abstract

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People need to know where objects are located in order to be able to interact with the world, and spatial language provides the main linguistic means of facilitating this. However, the information contained in the description about objects locations is not the only message conveyed; there is evidence in fact that people carry out inferences that go beyond the simple geometric relation specified (Coventry & Garrod, 2004; Tyler & Evans, 2003). People draw inferences about objects dynamic and objects interaction, and these information become critical for the apprehension of spatial language.

Among the inferences people draw from spatial language the property of the *converseness* is particularly appealing; this principle states that given the description "A is *above* B" one can also infers "B is *below* A" (Levelt, 1984, 1996). Thus if the speaker says "the book is *above* the telephone" implicitly the listener also knows that the telephone is *below* the book.

However this extra information does not necessary facilitate the apprehension of spatial descriptions. If it is true that inferences increase the amount of information the description conveys (Johnson-Laird & Byrne, 1991), it is also true that this "extra-information" can be a disadvantage. In fact the spatial preposition used in the description can end up in being ambiguous because it suits more than one interpretation: The consequence is a reduction of the *informativeness* (Bar-Hillel, 1964). Tyler and Evans (2003) called this inferential process *Best Fit*: Speakers choose the spatial preposition which offers the best fit between the conceptual spatial relation and the speaker's communicative needs. This principle can

be considered a logical extension of the notion of relevance (Grice, 1975; Sperber & Wilson, 1986) and an integration for the Q-Principle (Asher & Lascarides, 2003; Levinson, 2000a) according to which speakers have the duty to avoid statements that are informationally weaker than their knowledge of the world allows. This dissertation explores whether the inferences people draw on spatial representations, in particular those based on the *converseness* principle (Levelt, 1996), will affect the process that drive the speaker to choose the most informative description, that is the description that best fit spatial relations and speaker needs (Tyler & Evans, 2003).

Experiment 1 and 2 study whether converseness, tested by manipulating the orientation of the located object, affects the extent to which a spatial description based on the preposition *over, under, above, below* is regarded as a good description of those scenes. Experiment 3 shows that the acceptability for a projective spatial preposition is affected by the orientation of both the object presented in the scene. Experiment 4 and 5 replicate the results achieved in the previous experiments using polyoriented objects (Leek, 1998b) in order to exclude the possibility that the decrease of acceptability was due to the fact that one object was shown in a non-canonical orientation. Experiment 6, 7 and 8 will provide evidence that converseness generates ambiguous descriptions also with spatial prepositions such as *in front of, behind, on the left* and *to the right*. Finally Experiment 9 and 10 show that for proximity terms such as *near* and *far* informativeness is not that relevant, but rather it seems that people simply use contextual information to set a scale for their judgments.

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Chapter 1

Introduction

Language is the principal tool humans use to convey information about where important things are located (food, safety, enemies) and how to get to and from these places (Pinker & Bloom, 1990). Spatial language is well adapted to perform these functions through expressions containing spatial prepositions; for example "the book is *on* the table"[1], "the car is *in front of* the church", "the post office is *near* the market". However, information about spatial location is not the only message conveyed by a spatial description; there is evidence that people normally carry out inferences that go beyond the simple geometric relation specified (Coventry & Garrod, 2004). Tyler and Evans (2003) identified several inferential strategies that listeners employ in the apprehension of a spatial preposition such as inferences regarding the real-world force dynamics that involve the objects described. The description "the cat jumped *over* the wall" assumes that interlocutors have shared knowledge that goes beyond the simple spatial description, such as information that the cat does not fly and cannot hover above walls, and that the wall cannot be jumped through, etc. Coventry and Garrod (2004) showed that peo-

[1]From now, *spatial prepositions* will be written in italics whereas SPATIAL RELATIONS will be written in upper case.

ple draw inferences about object dynamics and object interactions that in turn become critical for the spatial language apprehension process. For example "the teapot is *over* the cup" indicates that the teapot is not just occupying the region above the cup, but also that the teapot is in the most appropriate position to interact with the cup (in the action of pouring the tea into the cup). Inferences which can be drawn on the representation of spatial scenes may also involve the property of *converseness* (Levelt, 1984, 1996); given the description "X is *above* Y" one can also infer the reverse representation, that is "Y is *below* X". Thus if the speaker says "the book is *above* the telephone" the listener also knows that the telephone is *below* the book. These are just few examples (out of several that will be discussed more in detail in the next chapter) of how people infer "extra" information from a spatial description that goes beyond information about the geometry of the scene being described.

Most often the "extra" information that a spatial description can convey serves to give the interlocutor useful information about the relationship between objects described. However sometimes this can be a disadvantage. Spatial prepositions used in the description can end up being ambiguous because they fit more than one interpretation. Accordingly, Tyler and Evans (2003) used the notion of *Best Fit* to delineate the process that drives speakers to choose the spatial preposition which offers the best match between the conceptual spatial relation and the speaker's communicative needs. This principle can be considered a logical extension of the notion of relevance (Grice, 1975; Sperber & Wilson, 1986) and an integration of the pragmatic Q-Principle (Asher & Lascarides, 2003; Levinson, 2000) according to which speakers have the duty to avoid statements that are informationally weaker than their knowledge of the world allows.

This thesis explores whether the inferences people draw with regards spatial relations, and in particular those based on the converseness principle (Levelt, 1996), affect the extent to which spatial descriptions are regarded as acceptable to describe those spatial relations. Four series of experiments investigated this issue with the following spatial prepositions: *Above, below, over, under, near, far, in front of, behind, on the left, on the right.* However, prior to presenting the experiments, we first need to examine more closely what spatial language is for, how spatial prepositions in particular have been treated in linguistics and psycholinguistics, and how inference and informativeness have recently been shown to influence the spatial language comprehension process.

1.1 What is spatial language?

The emergence of spoken language has been indicated by many to be the principal characteristic that distinguished human beings from animals. Spoken language provided humans with an invaluable and more precise tool than animals' primitive communicative systems, in particular when communication of food resources became a primary need for survival (O'Keefe & Nadel, 1978; Pinker & Bloom, 1990). If spatial cognition is the key process to build mental representations of the environment, spatial language is the instrument that maps these representations onto language, that is how people talk about space. In order for the mapping to take place, people encode a perceptual input into a linguistic event and following Jackendoff (1983; 1996) the brain encodes information in many distinct formats, similar to Fodor's concepts of modules (1983). The main modules are *conceptual structure* (CS) and the *spatial representation system* (SR)[1]: CS is the module

[1] Jackendoff's theory also includes a further module for language representations but given that this component is not of central interest it will not be considered here.

that addresses the encoding of linguistic meaning independent of the particular languages used. This representation refers to the *concepts* of the world rather than to the *perceived* world and is a predicate that expresses a spatial relation (Logan & Sadler, 1996). For example, the CS of the spatial relation ABOVE is the conceptual representation of the abstract relation between two objects vertically aligned on a 2-D plane. This sort of representation does not take into account other properties of the objects such as size, orientation, functionality, and so on. On the other hand, the SR encodes spatial information in a more geometric, almost topological way (following Marr's $2\frac{1}{2}$D and 3D sketch, 1982), providing a pictorial (or quasi-pictorial) representation of the visual information (similar to Brugman's "image schemata", 1988). This representation is formed automatically by local parallel processes and is, as Marr said (1982), "an obligatory consequence of opening one's eye" (see also Pylyshyn, 1984; Ullman, 1984 for a similar position). The connection between the two systems can be represented by the notion of physical object, which appears as a *geometrical unit* in SR and as a fundamental *algebraic constituent* type in CS. There is also evidence that the algebraic format is composed by lexical concepts, that is concepts for which there are words or morphemes in the speaker's language (Levelt, 1996). However, understanding how people map spatial concepts into language, is only the first step to understand how people use and understand spatial language.

Spatial prepositions are among the highest frequency words in English (Tyler & Evans, 2003) and are the principal linguistic tools of spatial language (Miller & Johnson-Laird, 1976). Spatial prepositions are usually classified into categories that reflect the region of the space that is taken into account during the apprehension process. Following Coventry and Garrod (2004) spatial prepositions can be classified as *directional* or *locative* (or *relational*). As the name suggests, the first are used to indicate a direction as in "the car move *backwards*" or the direction where a location is, as in "the river is *to the East*". On the other hand, locative prepositions indicate the location of an object(s) related to a landmark referent, as in "the book is *above* the table". Locative prepositions can be further divided into *topological* and *projective* prepositions (Coventry & Garrod, 2004). Topological prepositions express spatial relations concerned with topological concepts such as inclusion and contiguity on the one hand and proximity on the other. Simple topological prepositions express relations of the former form, such as *in* and *on*, whereas proximity prepositions express relations of the latter, such as *near* and *far*. Projective prepositions express relations in the dimensional structure of space by specifying a direction in three-dimensional space (Clark, 1973a) in which an object is located with respect to a reference location or object (Coventry & Garrod, 2004; Jackendoff & Landau, 1991). For example, in "the book is *above* the table" the projective preposition *above* expresses the direction in which the book is positioned with respect to the table.

Historically, spatial prepositions like *in* and *on* have been treated in terms of geometry alone: For *in*, the subject of the preposition must be INCLUDED IN, ENCLOSED BY or INTERIOR TO the object of the preposition. For *on*, "the book is *on* the table" the assumed representation is one of contact or contiguity between the book and the table together with the additional constraint of support for some of the definitions. Thus the semantic representation of the prepositions is primarily geometric, expressed through topological relations such as enclosure or spatial contiguity (Bennett, 1975; Herskovits, 1986; Leech, 1969; Miller & Johnson-Laird, 1976). For example the semantics of the spatial preposition *above* correspond with the area or a point directly higher to a landmark object (Logan & Sadler, 1996). Similarly, the spatial preposition *over* normally indicates "a location higher than, but not in contact with" a referent object (Brugman & Lakoff, 1988). The difference between these prepositions is that *over* has a region of acceptability smaller than the spatial preposition *above*: thus for a scene where the objects being described are not perfectly aligned, the spatial term *above* will be more appropriate in describing the spatial relation between the two objects (Coventry, Prat-Sala & Richards, 2001).

Further spatial preposition properties emerged from studies on language acquisition. Spatial terms start to appear in two year old children (Tomasello, 1987) and continue to develop during the first 8 years. The spatial prepositions *in* and *on* are the first morphemes to appear (Aguiar & Baillargeon, 1998; McLean & Schuler, 1989) followed by *under* that appears around six months later. Proximity spatial terms such as *next to* and *beside* start to appear from the fourth year, followed by projective spatial prepositions such as *behind* and *in front of* (Bowerman & Levinson, 2001). Given that such spatial terms need to refer to the intrinsic orientation of the objects, children begin to use these prepositions around the age of five, once they have learned to discriminate the face and the back of objects. The last spatial terms to appear are *above, over, between, left* and *right* (Johnston & Slobin, 1979). Such an order of acquisition (from *in, on,* to *under*, to projectives) has also been found across a range of languages. This has been cited as evidence that topological relations such as containment are conceptualised earlier than projective relations and there is a linear order underlying a parallelism between spatial cognitive development and linguistic development (for example, in English spatial preposition *in* is acquired before *in front of*). This evidence go together with the view that the development of spatial conceptualisation strictly reflects the order of appearance of spatial terms (Piaget & Inhelder, 1956). However, there is evidence that children use spatial prepositions initially with a non-spatial meaning, such as in "come *on*" in contradiction with the view that infants have to acquire the spatial meaning of prepositions first (Rohlfing, 2006).

Another common problem with studying how people describe spatial relations concerns the polysemy of spatial terms (Jackendoff, 2002) and how their meaning depends on the context in which they are used (Herskovits, 1986). Natural languages cover the whole range of linguistic expressions by a limited number of spatial relations showing the relevance of polysemy in lexical semantics (Landau & Jackendoff, 1993). For example, the spatial relation ABOVE is normally used to describe a spatial relation between two objects (for instance "the book is *above* the table"), but it can also be used to describe the status of people (e.g., "that colleague of mine is *above* me") indicating the hierarchy between two persons. Further examples of polysemy can be found in the domain of the time, where people map spatial terms into time expressions (e.g., "I'll see you *in* five minutes"; see Borodisky, 2001, for a discussion), emotion ("I'm feeling *up* today") and dead metaphors ("I'm *on* the wagon") (Coventry & Garrod, 2004). Spatial metaphors are a good example of where spatial prepositions are used beyond their spatial meaning. For Lakoff (1987) spatial representations are somehow basic and therefore act as productive vehicles for metaphors, and O'Keefe and Nadel (1978) claimed that in order to understand influence and social status metaphors such as "she was acting *under* his orders" assumes that people can be ordered on a status dimension, analogous to the vertical spatial plane. Interestingly, the same sentence does not accept the spatial prepositions *below* (e.g., "she was acting *below* his orders") suggesting that metaphorical uses of these spatial terms do not map only as a function of geometric relations (Coventry & Garrod, 2004). In other cases the same spatial relation conveys information that goes beyond the linguistic meaning: For example in "the airplane flew *over* Italy", the spatial term entails motion, or a change of position of the plane.

Spatial expressions containing spatial prepositions usually refer to scenes with two objects (though this is not always the case, for example with *between*): One object acts as a landmark (the so called *reference object*, hereafter RO), and a second object that is the object whose location has been described (the so called *located object*, hereafter LO). So, in a sentence like "the book is *over* the table" the book is the object we are looking for, while the table is the landmark. The terminology for the LO and RO is generally accepted but different terms are also used (see Retz-Schmidt, 1988, for a review): for example Talmy (1983) uses *primary* vs. *secondary* object whereas Lakoff (1987) calls the LO *trajector* and the RO *landmark*. Langacker (1986) instead, uses Gestalt terms such as *figure* and *ground* whereas Jackendoff (1983) named the objects *theme* and *reference object* respectively. Following Coventry and Garrod (2004), we will use *located object* and *reference object* in order to avoid the visual connotation associated with figure and ground and the movement connotation associated with trajector and landmark.

Selecting the LO in describing a scene is a process driven by a linguistic target. In fact, the speaker will point to the object that the listener is looking for; thus "the book is *above* the table" indicates that the listener is looking for the book. On the other hand, given that the RO plays the role of landmark in identifying the location of the LO, the process of RO selection takes into account other factors. First of all the RO must occupy a position that is known to the speaker as well as to the listener, in order to preserve the efficacy of the linguistic exchange (Clark, 1996). Once this criterion is met, people have the tendency to select bigger and more salient objects as RO: this explains why people prefer to describe Figure

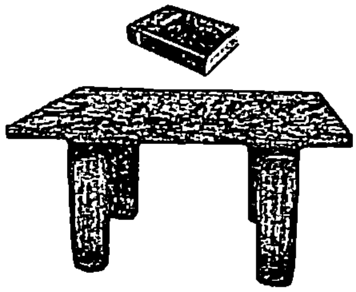

Figure 1.1: Any scene with two objects can be described in two complementary ways: "The book is *above* the table" or "The table is *below* the book". However people have the tendency to select bigger and more stationary objects as reference objects.

1.1 as "the book is *above* the table" rather then "the table is *below* the book" (Levelt, 1996). Similarly, Taylor, Gagnè, and Eagleson (2000) showed that the RO is usually the more stationary object; thus "the bike is *on the left* of the post-box" is more appropriate than "the post-box is *on the right* of the bike".

Although selecting the RO and the appropriate spatial preposition are necessary stages in the spatial apprehension process, there is a further fundamental mechanism that has to be considered of particular importance for projective terms; the selection of a reference frame. This step is critical when the speaker chooses which point of view to adopt to describe a scene. In the next section this concept will be discussed in detail as this is important for the rest of the thesis.

1.1.1 Reference frame theories and computation

A description like "the acrobat is *above* the chair" is easily understood by anyone who speaks the English language. However, in order to fully understand the message in the sentence (and the speaker's meaning), it is necessary to conceive the point of view that the speaker had chosen at the time of production of the description (Schober, 1993). In fact the orientation of the chair (RO) is fundamental to understand the spatial description. According to many theories of the use of spatial relations, identifying a RO and a LO is a necessary but not sufficient condition for using and understanding of spatial relations (Herskovits, 1986; Jackendoff & Landau, 1991; Miller & Johnson-Laird, 1976; Talmy, 1983); people also need to select a reference frame (Carlson-Radvansky & Logan, 1997). Reference frame (hereafter **RF**) selection has a different relevance depending on which spatial term is used; for instance "the park is *near* the church" does not necessitate knowing which way the church is facing. However, saying "the park is *in front of* the church" requires knowing which way the church is facing[1] in order to have a clear representation of the location of the park.

A reference frame is a $3D$ coordinate system that people use to map the perceptual representation onto the conceptual representation (Logan & Sadler, 1996). Levinson (2003) claimed that people use mainly three types of reference frames (but see Carlson-Radvansky & Irwin 1993, 1994; Jackendoff 2002; Levelt 1984; Marr & Nishihara 1978 for further discussion): the *absolute*, the *relative* and the *intrinsic* reference frame. The absolute reference frame (or environment-centred) is the point of view aligned with salient aspects of the environment, such as gravity or geophysical features such as cardinal direction (north-south). The relative reference frame (viewer-centred) is the frame selected from the viewer (egocentric) point of view (but see Schober 1993, for another interpretation based on the observer-centred perspective). The intrinsic reference frame (object-centered) is

[1]See Jolicoeur et al. (1993), for a description of the mechanism involved in finding the front-back of objects.

the reference frame generated from the object's point of view (the RO). For example, consider the scenes in Figure 1.2. In Figure 1.2B "the acrobat is *above* the chair" is true within the intrinsic frame of reference (i.e., with respect to the axes defined by the RO), but false with respect to the relative (viewer-centred) or absolute frames. In Figure 1.2C the expression is true for the relative and absolute frames, but is false for the intrinsic frame. In contrast, in Figure 1.2A the expression is true within all three reference frames. Alternative terms, but similar contents were proposed for the three basic types of frames of reference (Miller & Johnson-Laird, 1976; Retz-Schmidt, 1988): *Intrinsic* frames of reference are established on an anchor object that determines the origin of the coordinate system as well as its orientation, *extrinsic* frames of reference may also inherit their origin from an anchor object; however, their orientation is determined by external factors such as the direction of motion or by a conventional object used as landmark. Finally, the third is the *deictic* frames of reference involving three objects: A primary object that is in a particular relation with the respect to the reference object and the point of view. The orientation is imposed on the reference object as seen by the point of view. There are many alternative ways in which reference frames can be categorised (e.g., Jackendoff, 1996). For the remainder of this thesis we adopt Levinson's categorisation (Levinson, 1996b) given that this is used most frequently in research on spatial projective terms since 2000.

Selecting a RF has also the important function of linking the perceptual representation derived from a visual world, and the conceptual representation (Jackendoff, 1996) that is derived from the linguistic utterance that refers to the objects and their relations. This association is achieved by tuning a number of parameters that constitute the reference system. The parameters that define a reference system, and hence reference frames, are *origin, orientation, direction, scale* (or

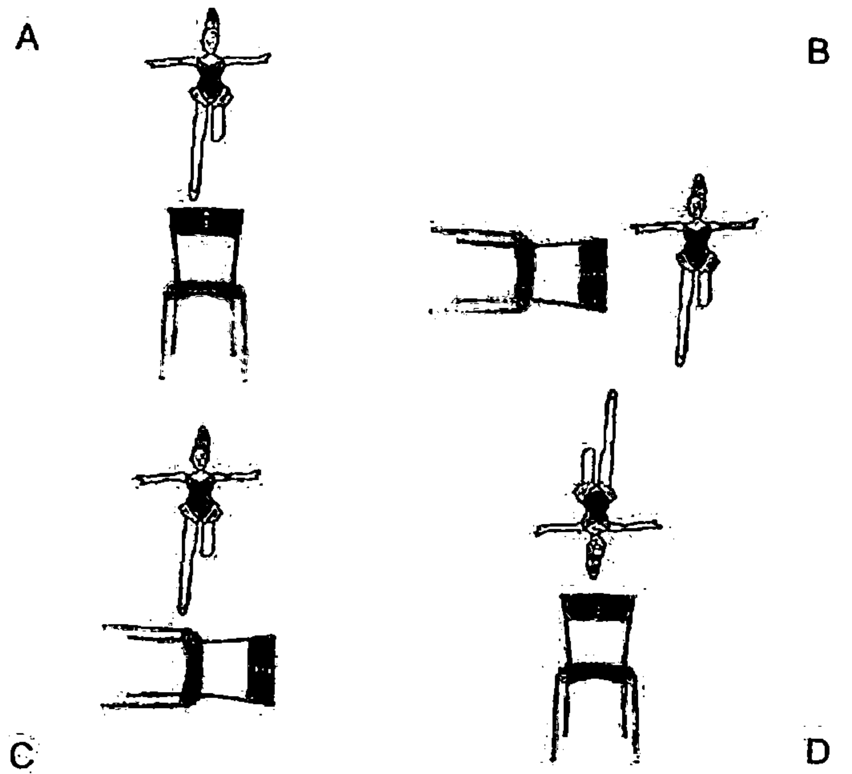

Figure 1.2: In "A" "The acrobat is *above* the chair" is true within the intrinsic, relative and absolute reference frames. In "B" it is true for the intrinsic frame but not for the relative frame or absolute frames, and in "C" it is true for the relative and absolute frames but not the intrinsic frame (assuming that the page is in canonical orientation).

distance; Logan & Sadler 1996). The *origin* is the center of the reference frame and is usually set directly on the RO (regardless the RF selected) since it is used as landmark. Setting the origin on the RO involves moving the origin of the coordinate system on the selected object. The origin can be set by spatial indexing, that is the process by which "a perceptual object is marked in the perceptual representation" (Ullman, 1984, page 500) and a symbol corresponding to it is set up in the conceptual representation (Pylyshyn, 1984, 1989). In other words this process sets a mapping between what is perceived and a symbolic representation.

Once the origin has been set, people have to establish the *orientation* of the RF. If the origin has been set on a non-canonical oriented object instead of a canonical oriented object (vertically oriented), the intrinsic reference frame has to be rotated in accordance with the object orientation. However, the absolute and the relative reference frames do not require any adjustment, because their orientations coincide with the gravitational plane. Orientation may be set by a process analogous to mental rotation (Corballis, 1988). After setting the origin and the orientation of RFs, people need to assign a *direction* to the space within the reference frame according to the spatial term. In other words, this stage consists in selecting the direction that best represents the orientation of the RFs' axes. For example we will activate vertical directions for spatial prepositions such as "*above/below*" and horizontal directions for spatial prepositions such as "*on the left/right*". The last parameter is the *scale* (or "distance" following Carlson & Van Deman, 2004) that simply indicates the distance between the origins of the RFs.

However, reference frame adjustment strictly depends on the spatial relation examined; in fact, not all the adjustments we discussed above are required for every relation. For example, the spatial relation NEAR requires setting the origin and the scale, whereas ABOVE requires setting the origin, orientation, and direction (Logan & Sadler, 1996). Reference frames can require a geometric alignment as in comparing the conceptual structure and the spatial representation (Jackendoff, 1983) but also a linguistic alignment. It has been shown that in a natural setting such as in dialogue, the speaker and the listener tend to align their utterances such that the conversation participants will come to communicate in a similar fashion to each other. According to Pickering and Garrod (2004) alignment is necessary to achieve a successful dialogue and a misunderstanding can originate if alignment is not reached. Alignment occurs when the two interlocutors employ equivalent representations, and reference frames provide a good example of a system that needs to be aligned for effective communication about the spatial world. In fact it has been recently shown that alignment does indeed occur for reference frames (Watson, Pickering & Branigan, 2004). Using a "confederate priming paradigm" (Branigan, Pickering & Cleland, 2000) a confederate and naïve participant were introduced as if they were both naïve participants with the instruction to describe, in turns, the location of objects to each other. Participants seated at computers on two desks side by side and had to decide which of two scenes on their screen matched their partner's description. The experiment revealed that speakers have the tendency to select the same RF they had just heard their interlocutor use, even when the speaker's (confederate's) description and the listener's (participant's) description involved different prepositions. This suggests that in dialogue people align non-linguistic as well as linguistic representations.

The application of reference frames to spatial language has been closely associated from a computational point of view with spatial template construction. A spatial template is a representation of the region of acceptability associated

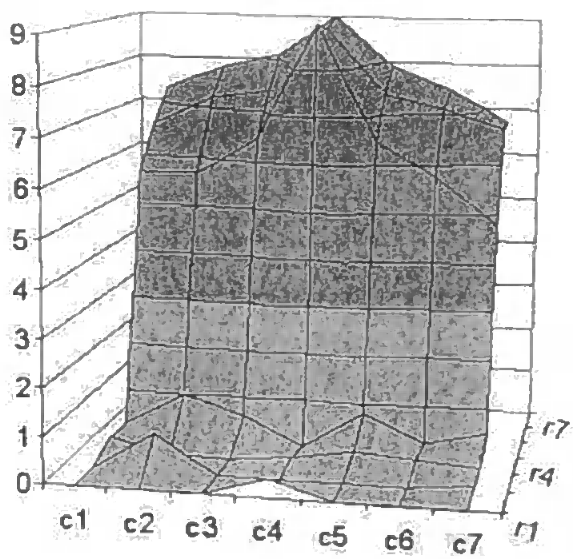

Figure 1.3: The spatial template for the spatial relation ABOVE constructed from Experiment 1 of Carlson-Radvansky and Logan (1997). The C1-C7 cells represent the rows of the grid, the y-axis represents the columns, and the Z1-Z7 cells represent the mean acceptability rating for the located object at each position within the grid. The reference object was in cell (4,4). Light grey indicates mean ratings from 0 to 3, middle grey from 3 to 6, and darker grey from 6 to 9.

with a given relation. Once the spatial template sets its origin on the RO and aligns with its reference frames, it defines the goodness with which the located object represents the spatial relation (Logan & Sadler, 1996). A spatial template can be illustrated as a matrix where people calculate the acceptability for a given spatial term (see Figure 1.3) and the acceptability of a spatial preposition reflects the reference frames activated on the scene described. Even though children prefer intrinsic specification of spatial relations more than relative or absolute ones (Piaget & Inhelder, 1956), there is evidence that adults use multiple reference frames and the appropriateness of a given spatial preposition is the weighted sum of the appropriateness calculated for each RF (Carlson-Radvansky & Irwin, 1993; Carlson-Radvansky, Covey & Lattanzi, 1999). Carlson-Radvansky and Logan (1997) asked participants to judge the appropriateness of a spatial preposition to describe a spatial array with two objects where the reference frames available were not coincident; sometimes the reference object was upright (canonical trials) and sometimes it was rotated, thereby dissociating the relative (object-centered) reference frame from the intrinsic (viewer-centered) and absolute (environment-centered) reference frames (noncanonical trials). The results showed that acceptability ratings reflect which reference frames were selected: Scenes where reference frames coincided were given higher ratings for *above* than scenes where frames did not coincide (i.e., where *above* was appropriate in a single frame). This suggests that people normally use more than a type of reference frame and the spatial template used for the judgment is a combination of spatial templates that mirror the absolute/relative and intrinsic reference frames.

In a series of experiments, Carlson et al. showed that spatial prepositions differ also in the shape and size of spatial template and their respective acceptability ratings mirror these parameters. For example the difference illustrated in the previous section between *above* and *over* can be explained in terms of different spatial templates: In fact the "acceptable" regions of the spatial template for the preposition *above* are more numerous than for *over* resulting in more appropriate ratings also for those objects not vertically aligned. Furthermore, given that the same representation can generate multiple reference frames in particular when the coordinate systems are not aligned, the final spatial template is the result of a weighted sum of all spatial templates activated in that moment (Carlson-Radvansky & Irwin, 1994; Carlson-Radvansky & Jiang, 1998; Taylor & Rapp, 2004). Thus, in Figure 1.2A the goodness of fit for the spatial relation ABOVE will be higher than in Figure 1.2C because the acrobat is in a "good area" only within two spatial templates (the absolute and the relative reference frame) whereas in Figure 1.2A the final template will be computed on three (the absolute, the relative, and the intrinsic reference frame) "good areas" and therefore showing a better goodness of fit.

Recently, an alternative view to spatial template computation has been proposed by Regier and Carlson (2001). They argued that attentional processes are central in spatial apprehension, in particular when the appropriateness of a spatial preposition is judged. Their model, the *Attentional Vector Sum* model (AVS), is a computational simulation that nicely predicts the acceptability for a number of spatial prepositions. The model is conceptualised as a population of vectors that are differentially weighted by attention. This simulates subneural system processes in which the overall direction of motion is represented (and predicted) by a vector sum over the population of cells of a set of constituent direction (Georgopulos, Schwartz, & Kettner, 1986). Logan (1994) found that visual search for a target in a visual field of distractors is slow when the target differs from distractors in the spatial relation between their elements, implicating a role for attention in the computation of spatial relations. The AVS model simulates the spatial apprehension process bringing together these two observations.

The model works by focusing an attentional beam on the reference object at the point that is vertically aligned with the closest part of the located objects (see Figure 1.4). Thus parts of the reference object nearest to the located object are maximally attended and more distant parts are attended less. This leads to a distribution of attention across the reference object. In addition, vectors are defined that are rooted at positions across the reference object and that point to the located object. This results in a population of vectors which are weighted by the amount of attention being paid at the location of their roots. The model then computes the sum over this population of weighted vectors, yielding an orientation that can be compared with the upright vertical. The principal factors included in the model are: *Proximity* and *centre-of-mass orientation*, *distance* and the *grazing line*. Proximity orientation is the angular deviation relative to upright vertical of a line connecting the closest two points of the LO and RO. Centre-of-mass orientation is the angular deviation of a line connecting the centre-of-mass of the LO and RO. The distance parameter indicates the distance between the RO and the LO. Finally, the grazing line is the line running through the topmost part of the RO. The model predicts that a distribution of attentional resources across the RO and the direction indicated by a spatial relation is defined as a sum over a population of vectors that are weighted by attention. Thus the spatial templates are here represented as a vector rather than an area. Although the AVS model deals only with few spatial terms, does not take into account the shape of the LO and only simulates a 2D space, it represents a clear advance over spatial templates.

In conclusion, spatial language is the principal communicative instrument to

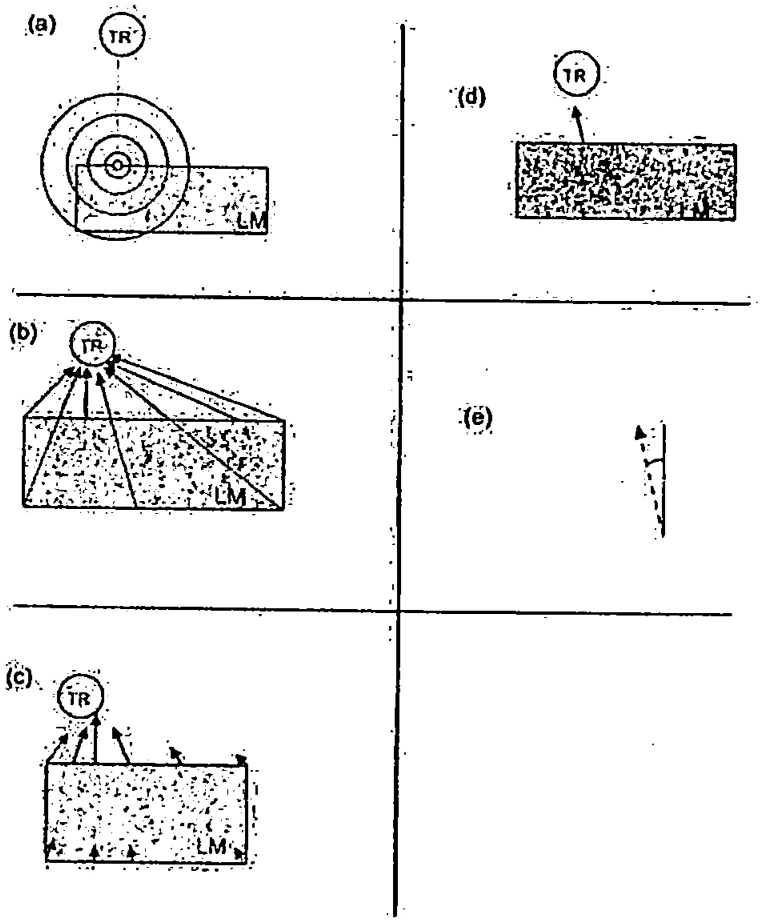

Figure 1.4: Here is illustrated the attentional vector-sum model. In "a" is represented the attentional field, focused on the reference object (LM), near the located object (TR). Different parts of the reference object receive different amount of attention. Panel "b" illustrates the vectors rooted at each point of the reference object, pointing toward the trajector. Panel "c" illustrates the attentional weighted vectors. Panel "d" illustrates the direction of the attentionally weighted vector sum. Panel "e" illustrates the orientation of the vector sum, relative to vertical upright.

convey information about the location of objects in the world (Talmy, 1983). Despite the ease with which people use spatial language everyday, the complexity of the processes required to apprehend a simple description such as "the book is *above* the box" has been shown above. This includes the instantiation of reference frames, and the stages of processing associated with the spatial apprehension process. Next we consider whether spatial language comprehension is sufficiently characterisable in terms of geometric relations alone.

1.2 What is spatial language for?

Thus far we have assumed that spatial prepositions relate to the geometry in the scene being described. Indeed, this was the position taken in up until the late 1980s in the spatial language literature, culminating in Landau and Jackendoff's (1983) influential paper where they argued for an association between different types of lexical items and the distinction between the dorsal and ventral visual pathways (cf. Ungerleider & Mishkin, 1982). Spatial prepositions refer to where objects are located, while nouns and other open class terms refer to what objects are. This view is in line with that proposed by Talmy (1983), where objects are schematized and do not contribute to the spatial relation associated with a spatial preposition in context.

1.2.1 Spatial language and geometry

In line with this view, a range of impressive theories of geometry can be applied to spatial prepositions. For example, the theory of *region connection calculus* (Cohn, Randell & Cui, 1995) claims that space can be divided in "regions". In doing that, this approach was able to explain, although only partially, the cate-

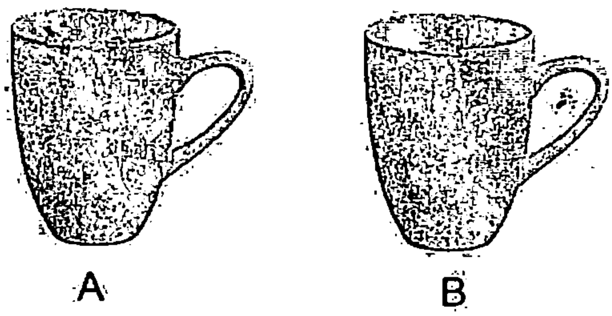

Figure 1.5: "The fly is *in* the cup".

gorisation of spatial relations using two primitives geometric features: *convexity* and *connection*. Cohn et al. explained the geometric concept of convexity pointing to a region of interior spaces (concavities), which can easily apply to spatial terms. Thus the strongest example for the spatial preposition *in* is when one region is completely surrounded by the other, although there are different degrees to which an object can be *in* another one. The basic geometric relation described by Cohn and collaborators (1995) properly captures these differences. However, there are scenes where RCC is not able to explain behavioral results completely. For example, Cohn et al's theory does not explain why people judge the fly *in* the cup when it is inside the cup (Figure 1.5 A) but not when it is *in* the handle (Figure 1.5 B); perhaps the handle might be considered not be part of the cup.

Ullman (1979; 1984) suggested that perceptual processing requires specialised visual routines that operate on the output, the *basic representation*, to yield a more flexible representation of the visual scene able to explain also the more extreme example of enclosure (visual routines as a spatial apprehension model).

Ullman's contribution was that perception alone is not sufficient to understand spatial relations between objects. In fact, *basic representations* do not contain information about spatial relations such as INSIDE/OUTSIDE: This kind of information can be acquired only by *visual routines*. These cognitive processes have been simulated also by Regier (1996) who employed a constrained connectionist network to learn to discriminate between dynamic scenes representing different spatial relations. Thus, similarly to the concept of a spatial template (Logan & Sadler, 1996) the space can be divided into regions that exhibit different degrees of spatial relations and the mechanisms are similar to Ullman's visual routines with the difference that the attention guides the direction of the spatial relations. The strength of this model resides in its property to simulate acceptability judgments that indicated how well a given spatial term describes the relationship between a located object and a reference object.

The geometric theorisation of space we have seen so far strongly suggests that spatial language is grounded in perception and that it aims to localise objects in space. However, as we shall see in the next section, there are serious shortcoming of approaches that attempt to ground spatial language in geometric relations alone (Coventry & Garrod, 2004; Tyler & Evans, 2003). Tyler and Evans provide evidence that principles of Euclidian geometry such as those mentioned above, do not hold at the level of conceptual structure (Talmy, 2000). Conceptualised space and spatial relations are topological in nature; that is they involve relativistic relationships rather then strictly fixed quantities. Thus the relation between the LO and RO can be distorted conceptually but its conceptualisation (*proto-scene*) remains constant. In accordance with the idea that geometric theories alone are not able to explain the spatial apprehension process, we will take into account *extra-geometric* components that integrate the models we have discussed above with object features and interactions.

1.2.2 Beyond geometry. The Functional Geometric Framework

As we noted above, Talmy (1983) originally argued that the principle aim of spatial description is the communication of the location of objects in space, and the properties of those objects do not affect the spatial relation conveyed by a spatial preposition. However, there are many examples in the spatial language literature showing that objects do matter for spatial language comprehension. More specifically, the specific functions that objects have, and how objects interact with each other, have been shown to be critical for spatial language comprehension. The importance of functional relations indeed can be traced back to Michotte (1963), who argued that "there is more to perception than meets the eye." He claimed that people infer causal relations between objects when objects are shown to move and contact each other in a now famous series of elegant experiments involving moving geometric shapes.

Consistent with the notion that forces between objects affect spatial language, studies in memory have shown that expectations about forces affect memory for object location. For example, among classic work on "representational momentum", Freyd et al. (1987; 1983) have shown that memory for object location is distorted in the direction in which an object falls in the gravitational plane. For instance, when an object is shown falling to the ground in a series of still photographs, people misremember the last position of the object as being lower than shown as if they had projected the object further in the expected direction of travel. Freyd et al. (1987; 1983) showed that both a dynamic as well as a static scene might involve force representation. The authors revealed that in a memory task the recall of a picture was distorted in the direction consistent with

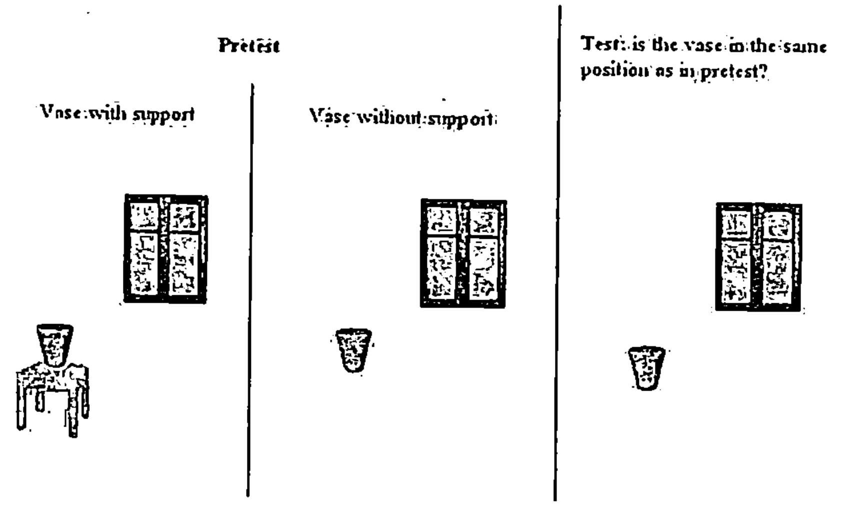

Figure 1.6: In the pretest stage participants were shown scenes with or without support. Then they had to judge whether the test-picture was the same as that presented in the pretest. People who saw the picture without support exhibited a distortion in the memory for the position of the vase in accordance with gravitational attraction.

what would happen if the LO (for example a plant) lost the support from the RO (see Figure 1.6 for an example).

There is much evidence that spatial preposition apprehension process similarly involves non-linguistic knowledge as well. Recently Coventry and Garrod (2004) classified these *extra-geometric* factors in two main categories: Either they relate to specific knowledge of how objects are likely to interact in standard situations or they relate to inferences about the dynamic aspect of the scenes being described. To start with some examples where geometric relations alone are not able to explain the use of spatial prepositions, we can look at Figure 1.7. In "A" the pear is within the convex hull of the bowl but in "B" it is not. Yet *in* is still

Figure 1.7: "The pear is *in* the bowl". Normally people use this spatial description for both the cases even though that in B the pear is not geometrically contained.

the most appropriate preposition to describe the location of the pear in "B" (Herskovits, 1980).

Location control has been proposed to be a component of the meaning of spatial prepositions such as *in* and *on* (Coventry, Carmichael & Garrod, 1994; Garrod, Ferrier & Campbell, 1999) and refers to the property that the reference object needs to be able to constrain the location of the located object. Thus the RO needs to be able to constrain the location of the RO such that moving the RO will cause the LO to move also (Vandeloise, 2005). Garrod, Ferrier and Campbell (1999) found evidence for the importance of location control for *in* and *on*. They presented video-clips of different arrangements of a pile of ping-pong balls and a glass bowl (see Figure 1.8). The first position shown, P1 has the ball (in black) in contact with the bottom of the bowl, at P3 it is level with the rim and for positions P4 and P5 it is above the rim. The second factor manipulated was the degree to which the location of the black ping-pong ball could be seen to be controlled by external source (attached or not to a thin wire).

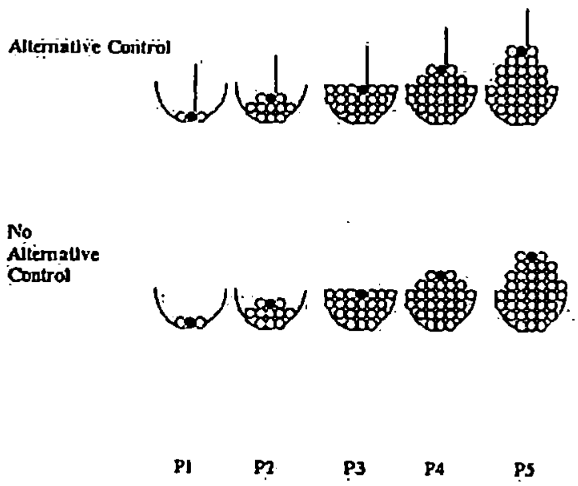

Figure 1.8: Schematic representation of the video-clips used in Garrod et al. (1999).

According to location control participants judging the position of the ping-pong ball as being *in* the bowl should relate directly to the degree to which they see the container (the RO) as controlling the location of the ping-pong ball (the LO). The results indicated that location control is an important component of containment when the enclosure of contents by container is not complete (Garrod, Ferrier & Campbell, 1999).

In another study (Richards, Coventry & Clibbens, 2004), 80 children aged from 3 to 7 were presented with similar video-clips as those used by Garrod et al (1999) and Coventry (1998). The scenes involved objects piled *in* and *on* containers and supporting surfaces. The results showed that even in the youngest age group, children used *in* as the first prepositional phrase most in the scenes where there was evidence of location control and least in the scenes that provided evidence against location control. These results show that children are sensitive to location control not long after they can reliably produce the prepositions *in* and *on*. The authors claimed that the meaning of such spatial terms depend on constraints involving the physical forces that objects exert on each other. The RO needs to physically control the location of the LO in the case of *in* and *on* for these terms to be appropriate (Vandeloise, 2005). The second type of extra-geometric relation involves object knowledge effects. According to Coventry, Carmichael and Garrod (1994) the spatial preposition *in* was used more and was rated to be more appropriate to describe the location of the apple in a bowl compared to the location of the apple in a jug with the exactly the same dimensions as the bowl. Moreover, adding liquid to the jug was found to further decrease the use and the rating of *in*. This indicates that the water makes the object-specific function of the jug more salient, further reducing the appropriateness of the container as a container of solids. Coventry and Prat-Sala (2001) replicate this result across a wide range of materials suggesting that *in* is affected by the objects-specific function of the reference object.

Extra-geometric factors are also important for projective spatial prepositions, such as *over, under, above, below, in front of* and *behind*. Evidence for this has been found by Carlson-Radvansky and Radvansky (1996). The authors showed that the presence of a functional relation between objects to be described influences the choice of reference frame used to describe the locations of those objects. A scene illustrating a postman standing near a postbox was preferentially described using an intrinsic description (the postman is *in front of* the postbox) when the postman was facing the postbox, that is the case where the LO and RO are shown in a functional relationship (Carlson-Radvansky & Radvansky, 1996). In contrast, when the mail carrier was facing away from the mailbox, then extrinsic-relative descriptions were preferred (the postman is *to the left* of the

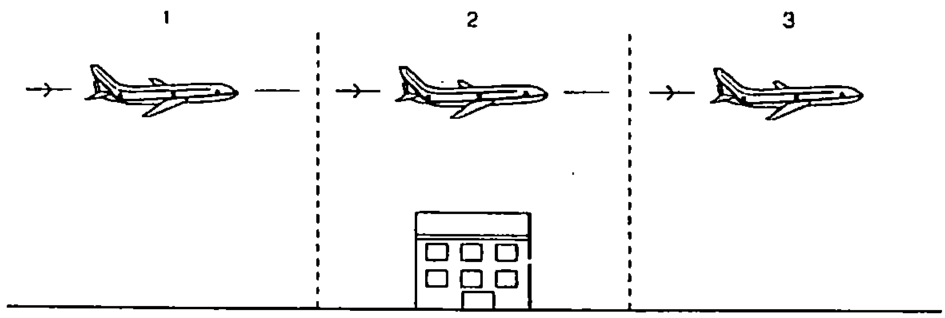

Figure 1.9: "The airplane is *over* the building" was considered more appropriate in describing the position of the plane in segment 1 than in segment 2 or 3.

mailbox). Therefore, the use of the intrinsic reference frame is preferred when the located object and reference object are in a position to interact with each other. In another experiment based on similar stimuli, placing a screen between the postman and the postbox lead the subjects preferring a relative reference frame (the postman is *on the left of* the postbox) showing that also the selection of a reference frame is affected by the functional relations between the two objects (Richards, 2001). In another study participants were required to rate the appropriateness of a sentence such as "the coin is *above* the piggy bank" using a scale from 1 to 7 (1 = not acceptable at all, 7 perfectly acceptable). The results showed that the appropriateness of the spatial preposition *above* was affected by the position of the coin relative to the position of the slot. In particular the highest ratings were assigned to the scenes where the coin was vertically aligned to the central slot rather than scenes where the coin was placed directly above the centre-of-mass of the piggy bank as one should expect (Carlson-Radvansky, Covey & Lattanzi, 1999).

These results are consistent with the idea that participants use what Coventry and Garrod term a dynamic-kinematic routine (of which location control for *in* and *on* is another example) to determine what would happen to the coin should it be dropped towards the piggy bank. If the coin is predicted to fall into a slot, then it is judged to be optimally *above/over* the piggy bank.

In a similar vein, Coventry and Mather (2002) provide empirical evidence in support of the idea that the appropriateness for the spatial prepositions *over* takes into account non-linguistic knowledge about how objects fall to the ground. Participants were shown a building which lies on the flight-path of an aeroplane, and were asked to indicate in which position they considered the plane to be over the building. There were 3 conditions; a control condition with no additional context and 2 experimental conditions in which participants were told that the plane was actually a fighter-bomber on a mission to bomb a building (condition two) or target (condition three) (see Figure 1.9). The authors found that in the context conditions, there was a significant association between where *over* was appropriate and judgements by the same participants as to where they thought the bomb should be dropped in order to successfully hit the building. Coventry et al. (2001) provided further support for the importance of force dynamics in the comprehension of spatial prepositions in a series of sentence-acceptability rating tasks. People were shown pictures where one object (the LO) had the function of protecting another object (the RO), such as in a man holding an umbrella to protect him from the rain (see Figure 1.10). Participants had the task of rating how appropriate a sentence as "the umbrella is *above/over* the man" was to describe the pictures. The results showed a strong effect of functional manipulation; the highest ratings were given to the scenes where the umbrella better protected the man from the rain (Coventry, Prat-Sala & Richards, 2001). In addition this experiment revealed an important properties of the spatial prepositions *above-below*

Figure 1.10: Sample scenes used by Coventry and Prat-Sala (2001) where the orientation of the LO (the umbrella) has been manipulated.

and *over-under* related to functionality. The results showed that only *over-under* were affected significantly more by function than geometry, while the reverse was true for *above-below*.

However, there is evidence that projective spatial prepositions are also affected by object knowledge. In another experiment, Carlson-Radvansky, Covey and Lattanzi (1999) presented a range of reference objects in which the functional part (e.g., the bristles of a toothbrush) was either aligned or misaligned with the object's centre of mass. They then presented pictures of different located objects which were either functionally related to the reference object (e.g., a toothpaste tube) or unrelated to the reference object (e.g., a tube of paint). The task for participants was to stick the picture of the located object above the reference object. They found that participants positioned the related located objects between the centre of mass and the functional part, and that the deviations toward the functional part were greater for the related objects than for the unrelated objects. Coventry, Prat-Sala and Richards (2001) also investigated the influence of object knowledge. They compared objects which do not have a known protecting function (e.g., a suitcase) with those that do (e.g., an umbrella or a shield) in order to investigate whether both the objects will still be judged as *over* the person to the same degree. While they found that the ratings for the inappropriate functional objects were lower overall than for the appropriate protecting objects, no interactions were found between this variable and any of the other variables examined. In other words, the effects of functionality and geometry were present for the non-stereotypically functioning objects just as they were with the stereotypically functioning objects. This is clear evidence that how objects are functioning in context is important, irrespective of our stereotyped knowledge about those objects.

In summary the extra-geometric effects reported in the literature fall into two categories. The first are effects due to knowledge of the specific objects in the scene and the standard situations in which those objects occur. The second type of effect has to do with interaction, which importantly relates to actual or potential dynamics in a scene, pointing to action as a key variable in formulating representations of objects in a scene. Coventry and Garrod (2004) developed a functional geometric framework where two types of extra-geometric constraints, dynamic-kinematic routines and knowledge of objects/situations, come together with what the authors term geometric routines in order to determine the situation-specific meaning of a spatial expression. Geometric and dynamic-kinematic routines ground spatial language in perception, and following Ullman's original notion of routine (1984), are optional and subject to attentional control. Dynamic-kinematic routines can therefore be regarded as another type of routine, distinct from the processing of geometry.

However, dynamic-kinematic routines and knowledge of objects/situations are not the only factors people consider in spatial language language especially when the context in which the communication takes place is taken into account. Garnham (1999) underlines the relevance of inferential processes in language comprehension claiming that "speakers and writers refer and hearers and readers must work out to whom or to what they are referring" suggesting that many aspects of communication are left to the inferential processes of the interlocutors. The next section will illustrate further examples of the fact that spatial language requires inferences in order to process all the extra-linguistic information.

1.3 Spatial Language in a wider context

In the previous section evidence has been presented in support of the idea that the apprehension of spatial language cannot be explained only by a geometric framework, but extra-geometric features need also to be taken into account. However, these relations are not the only relations necessitating inferences that people draw from language: Context has also been shown to be critical for spatial language processing. Within a scene where distance processing is required, spatial terms such as *near, far, close to*, and so on, do not specify distance alone (Coventry & Garrod, 2004). Langacker (1986), for example, showed that the way people use and understand spatial terms such as *close to* is affected by context. Imagine two small objects such as a pen and a key placed on a table one meter apart versus the same objects at the same distance but placed in an open space, such as a town square. The use of scale modifies the relative distance between the objects such that small distances become greater (on the table), whereas large-scale space (the square) adjusts relative distance such that small distances are reduced (Coventry & Garrod, 2004). Similarly, the objects being described can suggest the more appropriate scale; for example "the golf ball is *near* the hole" versus "the billiard ball is *near* the hole". The spatial prepositions *near* in the first example means that the ball could be several meters from the hole. In the second example, the context suggests that *near* does not indicate a distance bigger than few centimeters (Miller & Johnson-Laird, 1976). In another study where people were asked to rate the appropriateness of a spatial description in describing the distance, both the vehicle type (Ferrari vs. Robin Reliant) and knowledge about the driver (fast vs. slow) were manipulated. The results showed that *near* was more appropriate to describe locations in reference to the fast driver and the Ferrari than to the slow driven and the Robin Reliant. This indicates that subjects' judgments were affected by both knowledge of the likely speed of travel of the vehicle and expectation about the speed the driver was likely to drive at (Coventry, Mather & Crowther, 2003).

Spatial representation is also affected by the mobility of an object in the sense that people take into account the position that the objects will occupy in the immediate future. Under appropriate conditions, an observer's memory for the final position of an abruptly halted object is distorted in the direction of the represented direction of travel (Freyd, 1987; Freyd, Kelly & DeKay, 1983; Freyd, Pantzer & Cheng, 1988). There are also inferences that go far beyond the spatial contents of the spatial description but that are still necessary for the correct comprehension of the linguistic message. For example, "the cat jumped *over* the wall" assumes that the listener possesses knowledge beyond that conveyed by the simple spatial description, such as that the cat does not fly, the cat cannot hover above walls, that the wall cannot be jumped through, etc (Tyler & Evans, 2003).

The functional geometric framework also illustrated that spatial prepositions carry more than just geometric information about objects (Coventry & Garrod, 2004) because geometry alone does not support many spatial inferences. For example if one says that A is *in* B and B is *in* C, therefore A is *in* C is the logical conclusion. However, in spatial language this might not be case. In fact one could say that the wheel is *in* the driver's hand, that the driver's hand is *in* the glove, but we would not necessarily draw the conclusion that the wheel was *in* the glove. On the other hand, functional geometric relations such as containment or support allow a wider set of inferences to be made. For example, if one says that B contains A, we know that B has location control of A. Therefore we know that moving B it will affect the location of A as well.

Friederici and Levelt (1990) tested the assignation of reference frames and geometric axes in absence of gravity. The authors asked two science astronauts, who were part of the crew on a Spacelab, to provide spatial description of a number of objects. What they found was that although gravity was absent the two scientists were still able to assign reference frames using intrinsic-relative coordinates. Thus, with regard the spatial world, the lack of a main gravitational axis was not problematic. Different predictions could be formulated in respect to the dynamic-kinematic routines. In fact, this mechanism predicts that location control on the space shuttle should be different from that on earth as a function of different physical constraints: Thus "A is *in* B" could take quite different meanings depending on whether the speaker is on the earth or in the space where perhaps a lid might be required for containment to be said to contain an object in the absence of gravity. Similarly "A is *on* B" on the satellite requires the two objects to be attached. These examples illustrate how a functional geometric representation support a range of inferences that go beyond the simple geometry of the situation being represented reinforcing the idea that people draw inferences from spatial language in order to capture the full sense of the description. Among inferences people can draw from a spatial scene, in the next section we will focus on *converseness* (Levelt, 1984).

1.3.1 Converseness and informativeness

One of the most common inferences people draw from language regards the utilisation of words with opposite meaning. In English these are called *antonyms*, and include words such as black and white, rich and poor, tall and short and so on. The structure of spatial language itself allows people to draw inferences based on antonyms of spatial relations: Following the principle defined by Tyler and Evans (2003) a spatial description such as "the cat is *above* the hat" describes the location of the cat in relation to the location of the hat, however in this description one can also infer the location of the hat in relation to the location of the cat ("the hat is *below* the cat"). The logical property that allows this inference in language is called *converseness* (Levelt, 1984, 1996) and concerns only projective spatial prepositions such as *above-below, over-under, in front of-behind*.

Levelt (1996) first realised the relevance of the inferential potential of a spatial description. He argued, in line with Byrne and Johnson-Laird (1989), that spatial situations require reasoning, such as in spatial search instruction, following road directions, or spatial planning discourse. If the two-place relation expressed by one pole is called R and the one by the other pole by R^{-1}, then converseness holds if R(A,B) $\Leftrightarrow R^{-1}$ (B,A). For instance, if object A is *above* object B, B will be *below* A. Another inference people can draw from spatial language, also common in spatial reasoning (Byrne & Johnson-Laird, 1989; Tversky, 1991) is transitivity. This inference holds if from R(A,B) and R(B,C), it follows that

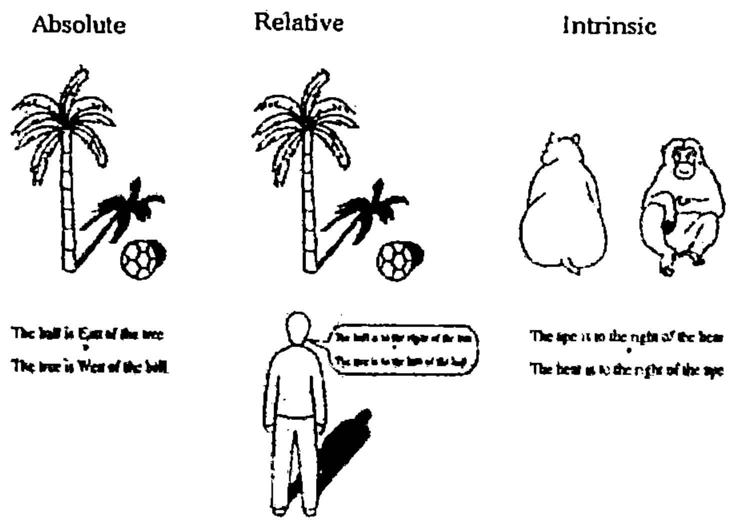

Figure 1.11: The logic of converseness is strictly connected to the reference frame that one can select. Reprinted from Levelt (1996).

R(A,C). For example A is *on the right of* B, B is *on right of* C, therefore it follows that A is *on the right* of C. There is an important connection between these two properties: both converseness and transitivity hold for the relative system and for most cases of the absolute system but not for the intrinsic system, showing that the potential for spatial inference is crucially dependent on the perspective system being used. For example, assuming that it is about noon somewhere in the Northern Hemisphere with the sun shining, the shadows of the tree and ball indicate that ball is east of the tree (see Figure 1.11). Using this absolute bearing the tree must be west of the ball where west is the converse of east. Converseness also holds for the (three-place) relative relation. From the speaker's point of view the ball (LO) is *to the right of* the tree (RO) which is necessarily implies that the tree (LO) is *to the left of* the ball (RO). But it is easy to violate converseness for the intrinsic system. The ape can be *on the right* side (*to the right*) of the bear at the same time as the bear is *on the right* side (*to the right*) of the ape. It is therefore impossible to infer the relation between RO and LO from the relation between LO and RO in the intrinsic system, which is problematic for spatial reasoning. Converseness is therefore important as a means of inference for this particular reference frame; I will be focussing on this inference for most of the thesis illustrating the connection with linguistic efficiency.

Statements like "please close your left eye" can easily lead to confusion if the speaker and the listener are not in agreement about whose point of view to use. Linguists and cognitive psychologists alike are interested in whether such ambiguities is occurred in spatial language are resolved during communication and what this might mean for the mental representation of space (Landau & Jackendoff, 1993; Levinson, 1996b). In this study we assume that ambiguous states concern the mapping between a sentence and a picture. A scene itself may accept different descriptions, and it is a speaker's duty to give an unambiguous description, that identifies the unique state of affairs in the picture - spatial world - being described. For example one can say "My car light is broken" or "My car light on the passenger side is broken" or "One of my car lights is broken; it is the one on the left side from the driver's perspective, or the right side if you and the car are facing each other". All these descriptions refer to the same scene but what makes them clear or ambiguous is a matter of the degree to which the sentence maps onto the unique spatial situation it aims to describe. So it is true that a scene can be described in different ways dependent upon the RO and the reference frame adopted but from the communicative perspective it is also the case that sentence themselves can be ambiguous for the description of the same scene. According to Taylor et al. (1999), spatial descriptions frequently contain ambiguities because they can be interpreted using more than one reference frame. Sloutsky et al. (1998) attempt to explain how people deal with ambiguity and indeterminacy of incoming information. The results of their studies showed that both young children and adults tend to reduce ambiguity, systematically converting noninformative propositions into more informative ones.

But what does distinguish an informative description from a non informative one? The formal treatment of *informativeness* has been proposed by Bar-Hillel (1964) who defined informativeness of a proposition as an inverse function of the number of states of the world that the proposition rules out. The formal relations are specified by the following equation:

$$inf(i) = -log_2 P(i)$$

where $inf(i)$ is the informativeness and $P(i)$ is the logical probability of the statement. This probability represents the number of states of the world where the proposition is true divided by the total number of all possible states of the world covered by the proposition. Thus, logical probability could be calculated using the following equation:

$$P(i) = \sum T_j / 2^n$$

T_j is a state of the world where the proposition is true and n is the number of atomic statements in the proposition. Let's see now an example of how this theory helps to understand the relation between *informativeness* and ambiguous descriptions. As we have stated above, the central assumption refers to the property of a description to rule out all but one representation; "My left car light is broken" then is not really informative because it does not clearly identify which light is broken. In fact it can be on the left side or on the right side as well on the rear or on the front, dependent on the perspective intended. "My car light on the passenger side is broken" suggests it is the left side that has been referred to. However if the car is made for the overseas market (with the driving wheel on the left side) the passenger side refers to the opposite side to a car produced for the British market. "One of my car lights is broken; it is the one on the left side from the driver perspective, or the right side if you and the car are facing each other" seems to be the most informative one because it excludes more interpretations than the previous descriptions, even if it is still ambiguous with respect to whether it is the rear or the front light that has been referred to. This example underlines the relevance of *informativeness* for description in general and for spatial description in particular where the number of possible interpretations grows proportionally with the number of elements in the scene and with the number of reference frames available.

It seems plausible then that if the tendency to reduce ambiguity stems from a cognitive constraint, then people would try to reduce ambiguity of non-informative propositions by increasing their informativeness. This tendency has been found in both adults and young children (Sloutsky, Rade & Morris, 1998) and seems to be a property of cognitive systems that have to deal with an environment in continuous modification. The tendency to reduce ambiguities to increase informativeness is particularly important within the domain of communication. Clark (1996) claimed that communication is a joint activity that requires coordinated action between a speaker and a listener. Schober (1993) as well emphasises the efforts the speaker makes in order to produce an utterance that meets the particular needs of their addresses. Thus people who want to deliver a successful message have to follow pragmatic rules such as *clearance* (Grice, 1989) and *relevance* (Sperber & Wilson, 1986) in order to reduce ambiguities[1]. Therefore descriptions, explanations, or declarations should follow informativeness princi-

[1]Pragmatic principles will be discussed in detail in the next chapter

ples in order to deliver a successful communication: Failing to do that, makes the communication unclear and therefore inefficient. Within the domain of language, *informativeness* can be seen as the unit of measurement of the quality of information carried by a sentence or utterance whereas pragmatics suggest that informativeness is not simply related to the number of linguistic elements in a sentence but rather to the way people use language to communicate, including inferences that people draw from the language.

But what is the connection between *converseness* and *informativeness* and why should this relationship be so important in spatial language? We have shown that people draw inferences from spatial language, and converseness is one of these. However this property can be counterproductive from a communicative point of view because it gives the possibility to generate multiple descriptions. For example with respect to the scene in Figure 1.11: the description "the ape is *on the right of* the bear" correctly locates the ape in the picture, but from an informativeness point of view, it nevertheless does not exclude the other state of the world such as that drawn by converseness "the bear is *on the right of* the ape". From the formal treatment of informativeness, given that this represents the probability of the number of states of the world where the proposition is true divided by the total number of all possible states of the world covered by the proposition, it is possible to calculate approximately the informativeness of the utterance "the bear is *on the left of* the ape" in referring to Figure 1.11. The states where this proposition is true is one, that corresponds to the case illustrated in Figure 1.11. The total number of all possible states of the world illustrated in the scene depends on whether converseness holds or not. If converseness holds the number of cases where it is true is lower than cases where converseness does not hold; in fact in the first case there are two possible states of the world: "the bear is *on the left of* the ape" and "the ape is *on the right of* the bear". However if the converseness does not hold there are three possible states of the world: "the bear is *on the left of* the ape" and "the ape is *on the right of* the bear" and "the bear is *on the right of* the ape". The consequence of this is that the formal calculus for the informativeness will return a higher result for the scene where converseness holds. Accordingly, the property of converseness turns out to be strictly related to the apprehension of spatial language because the speaker has also to increase the informativeness of a statement accordingly to the communicative principle (Asher & Lascarides, 2003; Levinson, 2000; Sperber & Wilson, 1986) in order to deliver a successful message. Therefore we have reason to think that converseness plays a central role in the spatial apprehension process, particularly in the final stage where the speaker decides what is the best (read as the most informative) description.

In summary, the spatial language literature is filled with examples, experiments and empirical evidence that suggest that spatial language carries more information than geometric information and that inferences are important for spatial relations. Among the inferences people draw from a spatial description, converseness turns to be essential for the apprehension of spatial language. However this logical property leads people to build up more descriptions for the same scene reducing the possibility to produce a clear, unambiguous communication (as it should be following the pragmatic principle). The central question tackled in this thesis is: Is converseness important for spatial language comprehension? As we shall see as the thesis unfolds, if converseness is important, this challenges some common assumptions regarding how spatial language processing takes place.

1.4 Précis of the thesis

The principal aim of the thesis is to examine whether informativeness, and specifically converseness, affects spatial language comprehension for a range of expressions containing spatial prepositions across a range of visual scenes. In chapter 2, the motivation for examining informativeness and converseness is examined in more detail. In particular the chapter examines the application of pragmatics to spatial language, and considers the analogy with recent work on spatial mental models showing that people do consider multiple models when presented with spatial expressions that are ambiguous (e.g., Byrne & Johnson-Laird, 1989). Accordingly we will adopt the concept of uniqueness in the sense that a spatial description should allow the construction of a single state of affairs for it to be maximally informative and unambiguous. Chapters 3 and 4 present a series of experiments examining whether converseness, tested by manipulating the orientation of the located object in visual scenes, affects the extent to which a spatial description is regarded as a good description of those scenes. The experiments reported focus on the projective spatial prepositions *over, under, above, below.* Experiments 1 and 2 show that the orientation of the located object does affect acceptability ratings given for spatial expressions containing these prepositions to describe given pictures. Experiment 3 shows that the acceptability for a projective spatial preposition is affected by the orientation of both the LO and the RO. These experiments illustrate that the orientation of the LO matters, and more importantly, it significantly affects the acceptability of a given spatial preposition. For scenes where the principle of converseness cannot be applied, the spatial preposition used to describe the scene become less appropriate because the spatial preposition becomes suitable for more than one configuration. Experiments

4 and 5 replicate the results achieved in the previous experiments but using poly-oriented objects, objects that are equally easily identified in any orientation in recognition tasks (Leek, 1998b). In doing that we rule out the possibility that the decrease in acceptability ratings for scenes where the LO was rotated over 90° in earlier experiments. The outcomes from an acceptability rating task (Experiment 4) and a sentence-picture verification task (Experiment 5) corroborate the hypothesis that the decreasing of acceptability is not related to recognition processes but rather to the multiple descriptions drawn by converseness.

Chapter 5 focuses on a new set of prepositions, including spatial prepositions such as *in front of*, *behind*, *on the left* and *to the right* with the aim of showing that converseness influences the acceptability of a wide set of spatial prepositions. Experiments 6 and 7 will provide evidence that people generate, by converseness, ambiguous descriptions also with these types of prepositions. In the same vein, Experiment 8 shows the effect of converseness within scenes where the activation of the intrinsic reference frame was implicitly required.

Chapter 6 examined proximity spatial prepositions, showing that the informativeness of a spatial description can be affected by extra descriptions, although the principle that generates these descriptions was not converseness (as converseness does not apply for proximity relations). Experiments 9 and 10 test this hypothesis.

Finally, chapter 7 will summarise the main results across the experiments and the consequences of our findings for the domain of spatial language. The impact of our results will also be related to previous theories of spatial language emphasising the relevance of considering spatial language within a communicative context.

Chapter 2

Spatial Language and communicative context

In the previous chapter we have shown that spatial prepositions convey more information than just geometric relations as illustrated by the Functional Geometric Framework (Coventry & Garrod, 2004); in fact spatial prepositions convey situation-specific information about how objects are interacting in context, of which geometry is a part. This thesis aims to extend this view investigating whether people draw other types of inferences not directly associated with functional relations but rather with the context in which spatial language is used. More accurately, we wish to test whether the Functional Geometric Framework extends beyond accounting for extra-geometric effects of "functional relations".

The communicative context within which we would like to broaden the functional geometric framework view is represented by the typical linguistic exchange between two people where communication is considered a joint activity that requires coordinated action between a speaker and a listener (Clark, 1996). Moreover, in order to be efficient, communication should meet some standards of informativeness, as claimed by the principal pragmatic theories. Grice (1975;

1989) formulated a general principle governing the use of language: "One should not make a weaker statement rather than a stronger one unless there is a good reason for so doing". This principle is part of a collection of maxims that follow from the overarching *Cooperative Principle* that includes four maxims: Maxim of *quality*, maxim of *manner*, maxim of *quantity* and a maxim of *relevance*. The first maxim declares that "people should not say what is believed to be false or for which one lack adequate evidence". The maxim of *manner* requires a speaker to "be brief, orderly avoiding ambiguities". The maxim of *quantity* says "make your contribution as informative as is required (for the current purposes of the linguistic exchange)" and finally the maxim of *relevance* says "do not make your contribution more informative than is required". Versions of these two informativeness maxims have featured centrally in recent neo-Gricean pragmatics (Asher & Lascarides, 2003; Horn & Ward, 2004; Levinson, 2000). The requirement that utterance content needs to connect up with existing assumptions and that the speaker should take account of the hearer's current cognitive condition are met by the more inclusive and fully cognitively-grounded Communicative Principle of Relevance which is at the heart of Sperber and Wilson's Relevance Theory (1986). In a communicative context such as conversation, the speaker and the hearer are satisfied when what has been said has been understood (Clark & Schaefer, 1987; Schober, 1993). In order to achieve that, the speaker structures his sentence considering the needs of the hearer and both partners actively collaborate with each other to ensure understanding in accordance with pragmatic principles (Schober, 1993). Therefore, spatial descriptions have to follow the same principles trying to be as clear as possible in order to deliver efficient communication. Similarly Tversky et al. (1999) claimed that "speakers select referent objects that are salient to communication partners and terms of reference that are relatively easy to produce and comprehend". Thus selecting a perspective represent the attempt to enable the easier reference terms and the more salient referent object.

From these pragmatic point of views ambiguous descriptions are those where a single interpretation is not possible. As a consequence of this the concept of informativeness, as realised by Bar-Hillel (1964), turns out to be strictly linked to the concept of *uniqueness*. In fact the most efficient way for a speaker to avoid ambiguities is to produce unique, well-distinguished descriptions, such that the listener immediately understands the speaker's intentions. The next section illustrates the principal pragmatic theories of language and their relation to the concept of informativeness. The importance of informativeness and uniqueness will also be discussed with reference to the mental model framework that has been instrumental in understanding human reasoning performance.

2.1 Pragmatic distinctiveness and mental models

Earlier in the thesis we suggested the hypothesis that spatial language and spatial comprehension are associated with the level of informativeness carried by the description, emphasising the importance of producing a clear utterance in order to avoid ambiguities. Many cognitive linguists (Jackendoff, 1983; Langacker, 1986) deny that there is any place for a distinction between pragmatics and semantics in their conception of the field. In contrast Levinson (1999) showed a number of properties of language that suggest that what people think and what people say do not coincide. Among the principles that Levinson describes, the most interesting for the present investigation is: "There is often an obvious gap between the *said* and the *unsaid* that is the domain of pragmatics" (Levinson, 1999, page 2).

Generally pragmatics is seen as the branch of linguistics that is concerned with the study of the divergence between the meaning of a speaker and the sentence meaning. In other words, pragmatics focuses on the study of how the context [1] affects the interpretation of a sentence. According to Leech (1983) pragmatics studies how people comprehend and produce communicative acts in a natural setting such as conversation. Leech observes that in a communicative act two intentions can coexist: The *informative intent* that is the meaning carried by the sentence, and the *communicative intent* that is the meaning of the speaker. The ability to fill the gap between these two levels of representation is referred to as pragmatic competence. Watzlawick, Beavin-Bavelas and Jackson (1967) suggested that any interaction between two (or more) people can be considered a form of communication where any action (speech, gesture, facial expression, etc.) carries a meaning for the other person, becoming a message itself. Indifference, for example, such as apathy demonstrated by an absence of emotional reactions, can be interpreted as a communicative message. Moreover the communicational setting requires an aspect of meta-cognition that defines the participants' relationship: For example, in giving an order, the speaker implies his relationship with the listener (that could be an employer, a slave, a soldier, and so on).

Austin (1962) is still considered by many as the principal pragmatic theorist. His main contribution can be summarised under the "Theory of Linguistic Acts", that demonstrates how "to say" implies "to do" or "to make something happen". He distinguishes between *locutory* acts (actions that exist just because we are talking about it), *illocutory* acts (that mirror the speaker intention, such as judging), and *perlocutory* acts (actions that have an effect, a consequence, such as giving a recommendation). Searle (1979), for example, focused on the illocutory acts, that are the acts that "say" something. Let's see some examples:

[1] Here the word context refers to any relevant factor.

- Sam smokes
- Does Sam smoke sometimes?
- Sam, smokes sometimes!
- I wish Sam would smoke sometimes

All these sentences use mostly the same words, but they differ in terms of illocutive power; in fact they can be defined respectively as an utterance, a question, a command, and a desire.

The implicit intention of the speaker, or the "sentence intentionality", is a central concept in Searle's theory (1979) as well as for spatial language. In fact, in producing a spatial description people should take into account the reason why this description has been produced, that is communicating the location of the objects or, following Coventry and Garrod (2004), providing information about how objects are interacting in the scene being described. The idea that communication should meet some standard of informativeness is central for another important exponent of this approach: H.P. Grice (1975). Grice studied how utterances are used in a discourse and how they are interpreted within a specific context. Grice's main point is that communicative acts are mainly based on the reciprocal expectative of cooperation between speaker and listener. Thus the speaker, with the act of speaking, communicates that what is being said is pertinent. The listener, on the other hand, should be informative (*maxim of quantity*), honest (*maxim of quality*), pertinent, clear, not ambiguous (*maxim of manner*), and short; "...make your contribution such as it is required, at the stage at which it occurs, by the accepted purpose or direction of the talk exchange in which you are engaged" (Cooperative principle; Grice, 1989, page 26). Grice also claimed that the logical rules that govern communication cannot explain completely how conversation works. In order to fulfil the cooperative principle, given that a dialogue is the result of a cooperation between two people with a common goal, both the speaker and the listener should share the same cognitive environment thus the listener can interpret the speaker intention.

A consequence of the cooperative principle is *conversational implicature*, that are meanings that are not explicitly expressed in what is said. An example can be found with disjunctive utterances "P or Q". A statement of either "P (is true)" or "Q (is true)" would be stronger than the disjunctive statement so the speaker is taken to have implicated that she is ignorant of the truth-values of the disjuncts: She does not know P to be true and she does not know Q to be true. Similar to Grice's maxim, Strawson (1952, page 178) claimed that "...one does not make the (logically) lesser, when one could truthfully (and with greater or equal linguistic economy) make the greater claim". The same author mentioned two general commonplaces which he called the "Principle of Relevance" and the "Principle of the Presumption of Knowledge" (Strawson, 1971, page 92). The first of these is intended to capture the undoubted fact that "people do not direct unconnected pieces of information at each other, but on the contrary intend to give or add information about what is a matter of standing or current interest or concern". The second says that "statements, in respect of their informativeness, are not generally self-sufficient units, free of any reliance upon what the audience is assumed to know or to assume already, but commonly depend for their effect upon knowledge assumed to be already in the audience's possession".

The requirements that utterance content connect up with existing assumptions and that the speaker take account of the hearer's current cognitive condition are met by the more inclusive and fully cognitively-grounded communicative principle of relevance which is at the heart of Sperber and Wilson's theory (Sperber & Wilson, 1986). Sperber and Wilson (1986), suggested that people can use implicit ways to communicate: For example by making interpretative inferences that communicate to the listener information that was not explicated. The main contribution of these authors was the *Relevance Theory* where there are unique properties that define which information will reach the listener: "Use the newest information using the least amount of effort". This theory, generated from a revision of the Gricean principle of relevance, claims that the process of understanding other people's sentences is strictly connected to the mental heuristics the listener is able to use. No workable pragmatic system involving informativeness is able to function without drawing on considerations of relevance. The general agreement that the main goal of spatial language is the communication of locations implies that people must also comply with communication rules and informativeness parameters. Therefore the speaker is expected to provide the listener with the most informative, true and univocal description.

Within the context of philosophy of language, *uniqueness* is relevant in the sense that a speaker must refer his intention unequivocally: For example it has been proposed that proper names assume the role of instrument to discriminate individuals uniquely (Searle, 1979) because a proper name sticks to the same individual across all situations, in the present, past and future (Putnam, 1975). Uniqueness is a key issue in memory research as well as in language. For example it is largely accepted that more distinctive the items are, the better the recall because interferences are reduced; this is true for word recall (Saint-Aubin & LeBlanc, 2005), false memories (Dodson & Schacter, 2002; Schacter, Israel & Racine, 1999) and face recognition (Shepherd, Gibbling & Ellis, 1991).

In relation to spatial language comprehension, work on spatial reasoning indeed suggests that spatial language processing involves sensitivity to uniqueness and informativeness. Mental Model theory is one of the most important theories of inductive and deductive reasoning, and is based on the assumption that people reason by manipulating models (representations) of the world (see Johnson-Laird & Byrne, 1991 for a review). As a consequence, more complex tasks require more complex models, making the manipulation of the entire representation more difficult. In this regard Byrne and Johnson-Laird (1989) presented an experiment in which people were asked to solve spatial reasoning problems with the same structure as Problem 1 and Problem 2 illustrated below.

Problem 1	**Problem 2**
A is on the right of B	A is on the right of B
C is on the left of A	C is on the left of B
D is in front of C	D is in front of C
E is in front of A	E is in front of A

Where is D in relation to E?

Participants were asked where D is in relation to E. According to the descriptions, the solution for both the problems is: D is *on the left* of E. However, in problem 1 there are two models consistent with this solution, whereas problem 2 generates a single model representation (as illustrated below).

Problem 1

Solution a

B C A

D E

Solution b

C B A

D E

Problem 2

C B A

D E

This experiment, and other similar studies, showed that people took more time and produced more errors to solve problem 1 than problem 2, even though the descriptions lead to an identical solution (Byrne & Johnson-Laird, 1989; Carreiras & Santamaria, 1997; Schaeken, Johnson-Laird & d'Ydewalle, 1996a,b). The explanation relies in the fact that in order to solve problem 1, people construct two models instead of one. Thus, the description in problem 2 is easier because no interference will emerge between representations, since a single well defined, unique model has been generated.

The hypothesis that problems with multiple solutions are more difficult is perhaps better represented by those problems where there is a lack of a valid conclusion[1] which are the hardest of all (Byrne & Johnson-Laird, 1989). For ex-

[1] In reasoning a conclusion is "valid" when it is true given that the premises are true thus indeterminate invalid problems are those problems in which the two models support different

ample given the premises

B is on the right of A

C is on the left of B

there are two possible solutions:

Solution a

C A B

Solution b

A C B

In this case the difficulty originates from the indeterminacy of the problem because it supports two possible solutions. This finding suggests that problems which support multiple representations that are inconsistent with one another are more difficult for people to process compared to problems that support the same conclusion.

These body of work shows that indeterminacy generated from the coexistence of multiple models is pertinent for spatial language. Extending this work, and consistent with the Functional Geometric Framework, one can argue that spatial expressions that identify unique, single models of the world, will decrease hearer cognitive effort, and as a result are comprehended most easily.

Now consider Figure 2.1. In relation to current theories of spatial language, the located object (the cat) is only of relevance if functional relations hold be-

conclusions.

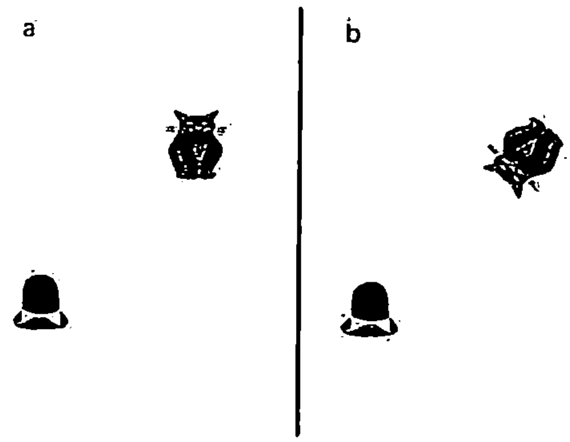

Figure 2.1: Two spatial descriptions can be used to describe the objects in "a": "the cat is *above* the hat" and "the hat is *below* the cat". In "b" when an intrinsic reference frame is selected the location of the objects refer to the same spatial relation (ABOVE) "the cat is *above* the hat" and "the hat is *above* the cat".

tween the objects in the scene. Moreover, as we have seen above, most accounts of spatial language assume that the located object is unimportant for the comprehension of a spatial expression. However, if uniqueness and informativeness are truly important for spatial language comprehension, then there are consequences of this for spatial language processing. Stating that "the cat is *above* the hat" for (a) allows the inference (via converseness) that "the hat is *below* the cat", but this is not the case in (b) ("the hat is *below* the cat" is false for the intrinsic reference frame). Hence, the sentence "the hat is *below* the cat" should be judged as more informative in (a) because this description identifies unique BELOW relation for the scene. In order to understand this step, we will describe explicitly all the descriptions available for a given scene. In "a" we have the following descriptions generated using all the possible point of view (absolute, relative and intrinsic reference frame):

- the cat is *above* the hat
- the hat is *below* the cat

In scene "b" we have the following descriptions.:

- the cat is *above* the hat
- the hat is *below* the cat
- the hat is *above* the cat

Thus, if we ask people to judge the appropriateness of the sentence "the cat is *above* the hat" in both the scenes, we may find higher values in "a" than in "b", because in "b" among all the possible descriptions, we have one that is based on the same identical spatial relation (in this case ABOVE). This is in contrast with the concept of uniqueness and it should affect the overall informativeness as illustrated in the previous chapter.

This prediction is at odds with traditional approaches to spatial language that claim that the function of spatial language is simply to narrow the search for an object in relation to a second known object (Landau & Jackendoff, 1993; Regier & Carlson, 2001; Talmy, 1983). In fact, following these approaches, rotating the LO (as illustrated in figure 2.1 b) should not affect the apprehension of spatial language. On the other hand, following the principle of uniqueness together with the concept of informativeness discussed in this chapter, and consistent with the Functional Geometric Framework, the number of descriptions available in a given scene should be associated with the acceptability for spatial expressions used just as the number of models is associated to the difficulty of a reasoning problem. In other words the informativeness principle indicates that the most informative model is the one that supports the strongest inferences about the situation that are consistent with the information present in the scene itself.

The experiments in chapters 3 and 4 set out to test whether the orientation of the located object affects spatial language comprehension for superior and inferior terms. Chapter 5 examines whether converseness is important also for horizontal project terms.

Chapter 3

Projective Spatial Prepositions: *Over, Under, Above, Below*

3.1 Introduction

As we have seen in the previous chapters, projective spatial prepositions on the vertical plane, namely *over, under, above and below*, require reference frames to be established for their interpretation. Following Levinson (1996a), people use mainly three types of reference frames: Absolute, relative and intrinsic. The absolute reference frame represents the point of view aligned with salient aspects of the environment, such as gravity or geophysical features. The relative reference frame is the frame selected from the viewer (egocentric) point of view. Finally the intrinsic reference frame is the reference frame generated from the object's point of view (the reference object). There is much evidence that reference frame assignment takes place with respect to the reference object alone, because the process of searching for the located object starts from this object (Carlson, 1999; Carlson-Radvansky & Irwin, 1993; Carlson-Radvansky & Logan, 1997). So "the book is *above* the table" requires the assignment of a reference frame centred on the reference object (the table), in order to give a direction to the space that allows the listener to localise the located object (the book).

However, if converseness is important for the comprehension of these terms, then there are consequences for reference frame assignment that will be considered later in the thesis. The main goal of the experiments in this chapter was to establish whether the orientation of the located object does affect the extent to which a spatial description of the form "object A is *over/above/under/below* object B" is rated as being appropriate to describe a given scene involving those objects. Experiment 1 employs an acceptability rating task and this paradigm is the central methodology used in later experiments also.

This paradigm is a modified version of the more common sentence-picture verification task (Clark & Chase, 1972; Seymour, 1969, 1974) which involved the presentation of a sentence followed by a picture of two symbols, a star ($\star$) or a plus (+) above or below each other and required participants to verify whether the sentence (e.g., "the star is *above* the plus") correctly describes the picture. The findings suggest that people convert both images and sentences to a propositional nonvisual format before they can be compared. Clark and Chase's model (1972) included five main stages: In stage 1 the sentence is first read and then translated into a propositional form while in stage 2 the picture is encoded as a proposition. In stage 3 and 4 the comparison between the two propositional representations takes place by matching the subjects of the propositions; here a number of truth indices indicate whether the there is match or not. In the final stage, stage 5, a response based on the current value of the truth index is initiated (Clark & Chase, 1972; Trabasso, Rollins & Shaughnessy, 1971). Other studies have shown that this stages sequence may lead to different results because people are prone to use mainly two different comprehension strategies, one verbal and one pictorial

(Mathews & Hunt, 1980; Reichle, Carpenter & Just, 2000).

There is evidence that in order to investigate the apprehension of spatial prepositions, speeded sentence/picture verification tasks and acceptability-rating judgments generally show the same pattern of performance (Carlson-Radvansky & Irwin, 1993, 1994). We decided to opt for the latter because this paradigm encourages graded judgments and as such it may be more sensitive to the effect of the orientation of the LO on the use of projective spatial prepositions such as *above, below, over* and *under*. Comparing the acceptability rating judgments with the verification task processes, most stages people go through are the same. In fact even with this paradigm people transform the sentence and the figure in a propositional form before the comparison between the two propositional representations takes place by matching the subjects of the propositions. At this point people in order to evaluate the goodness of fit between the spatial description and the given scene they have to deal with a number of steps usually described as *Spatial Apprehension Process* (Carlson-Radvansky & Logan, 1997). This process includes identifying the reference and the located objects, selecting a reference frame and build in the relevant spatial template combining them while taking into account their weights, processing the goodness of fit for the located object and finally determining whether the goodness of fit measure for the LO is high (good or acceptable region) or low (bad region). This sequence of events is comparable to those required in production with the difference that after the computation of the goodness of fit people have to select the most appropriate spatial preposition instead of deciding whether the given spatial prepositions fits the scene. However, for almost all the experiments an acceptability rating task has been adopted because it seems to be more sensitive in capturing the differences of the effect of the orientation of the LO.

In Experiment 2 we showed more orientations of the LO and more types of objects than in Experiment 1 and in Experiment 3 both the orientation of the RO and the LO are manipulated: This experiment is particularly relevant since it investigates multiple reference frame conflict together with the effect of converseness. In these experiments we expect that manipulating the orientation of the LO (Experiments 1-3) and the orientation of the RO (Experiment 3) will affect converseness and, as consequence, scenes where converseness does not hold (i.e., "the cat is *above* the hat" with the cat pointing toward the hat as illustrated in the Figure 2.1 b) will receive lower acceptability ratings compared to scenes where converseness does not hold.

3.2 Experiment 1

3.2.1 Introduction

In this first experiment we explore the idea that the orientation of the located object affects the way people use spatial language to describe a scene. Previous experiments have shown that the reference object has a central role in the spatial apprehension process (Carlson, 1999; Carlson-Radvansky & Irwin, 1994; Logan, 1994; Taylor & Rapp, 2004) especially in the process of assigning a reference frame. In these studies the orientation of the RO was manipulated resulting in a modification of the acceptability for the spatial preposition under study. For example the spatial preposition *above* in scenes where the RO was rotated of 90° was judged less acceptable because the intrinsic frame was misaligned with the relative/absolute frames.

In this first experiment the hypothesis that also the orientation of the LO affects the way people use spatial prepositions was investigated. In particular

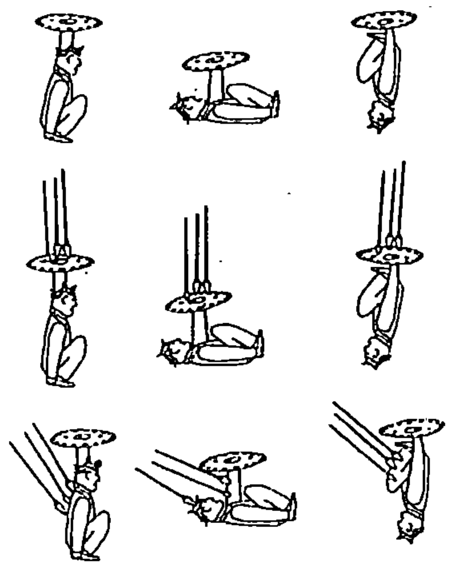

Figure 3.1: Here is illustrated an example of stimuli used in Coventry et al. (2001).

we predicted that scenes with the LO in a non-canonical orientation (but see below for the detailed predictions) will decrease the acceptability for a given spatial terms because this generates more situations (states of the world) where the the same spatial term will be suitable. This, accordingly to the principle of informativeness (Bar-Hillel, 1964), will result as being less informative and consequently the description will became less acceptable because it does not fulfill the basic pragmatic principle of communication.

In addition, we were also interested in seeing whether the effect is stronger for some prepositions than for others comparing the so called functional prepositions (*over* and *under*) and the geometric prepositions (*above* and *below*). This distinction has been first pointed out by Coventry et al. (2001) who showed that the appropriateness of a spatial description in describing a picture was significantly affected by the functional relations between the two objects in the scene. Figure 3.1 shows examples of scenes where participants were asked to judge the appropriateness of a sentence containing a spatial preposition in describing the location of the shield with respect to the viking. The scenes on the left represent the condition where all the reference frames were aligned. All the other scenes show cases where the absolute/relative and the intrinsic reference frame do not coincide. The authors found that the conflict among reference frames affects the appropriateness of the spatial terms *above/below* consistent with the results reported in literature (Carlson, 1999; Carlson-Radvansky & Irwin, 1994) but not by the functionality manipulation. Conversely *over/under* were affected by the functionality but not by the conflict among reference frames. These results provide evidence that both geometric and functional relations are factors influencing the appropriateness ratings of spatial prepositions but also that these factors affect spatial prepositions differentially. In the light of these results a similar distinction between preposition sets has been included in the following experiment where the *above/below* set and the *over/under* set were treated as factors.

3.2.2 Method

Participants

Thirty-two undergraduate students (29 females and 3 males; age ranged from 18 to 25, mean age = 19) participated in the experiment for course credit. All the participants were English native speakers with normal, or corrected to normal, vision.

Design and Materials

The experiment employed an acceptability rating task where participants had to rate the acceptability of sentences containing the spatial prepositions *above, below, over and under* to describe pictures. Scenes used Intrinsic Axis Objects (IA) such as a cat, a man, a house, etc, that are objects with an internal reference frame (i.e. the location of its principal axes) (Corballis, 1988). The four orientations for the LOs were: "vertical", "upside down", "pointing at" (the RO) and "pointing away" (from the RO). In the "pointing" conditions, the axis of the LO was pointing exactly towards, or away from, the center-of-mass of the RO as illustrated in Figure 3.2. Given that the conditions in which the LO is "pointing at" and "pointing away" the RO depend upon whether the LO is *above* or *below* the reference object, different predictions can be made on this regard. In particular we expect an interaction between "pointing at/away" orientations and superior/inferior terms while no interaction should emerge between "vertical/upside down" orientations and superior/inferior prepositions but only main effects.

The distance between LO and RO was always strictly controlled across all the orientations. Figure 3.2 also shows examples of the 10 locations where the LO appeared around the RO: 5 locations above the RO and 5 locations below the RO. Locations 1 and 6, 2 and 7, 3 and 8, 4 and 9, 5 and 10 were vertically aligned. Locations 3 and 8 were included for completeness, but not as a level of orientation for subsequent analyses (because for Oriented Axis objects upside down and pointing at levels are the same). The RO was always a picture of a football (a No Axis Object - NA - that are objects without a salient axis). We also included scenes with Non Directional Axis Objects (NDA) as LOs as filler items. NDA objects are those objects that have a main axis but not a clear direction. For example, an hourglass has a clear, well-defined vertical axis, but it is not possible to say where its top or bottom is (intrinsically). This parameter changes

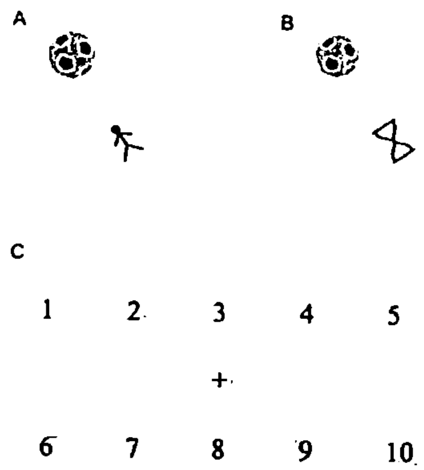

Figure 3.2: In "A" the stickman is "pointing at" the football. In "B", the hourglass is "pointing at" the football. In "C" are illustrated the locations of the LO around the RO (here represented by a plus).

in conformity with the gravitational plane that often overlaps with the vertical plane (Jolicoeur, Ingleton, Bartram & Booth, 1993). The whole set of objects used as LOs therefore included 8 Intrinsic Axis Object and 8 Non Directional Axis Object (see Appendix A for a full list of materials).

Each full scene (RO and LO) was presented in random positions on the screen so that participants did not see the RO always in the same location (in the middle of the screen). The design (for the oriented axis objects) included the following factors; 2 (superior/inferior spatial prepositions: *above-over* vs. *below-under*) x 2 (preposition sets: *above-below* vs. *over-under*; following the distinction found by Coventry *et al.* 2001) x 2 (proximity: LO far from the RO or the LO near the RO), x 4 (orientation of LO: "vertical", "upside down", "pointing at" and "pointing away") x 8 (LO objects), resulting in a subtotal of 256 trials. Half of the trials presented the LO to the left of the RO, and the other half presented the LO to the right of the RO. In addition there were 128 extra trials where the LO was in the central location, and a further 192 trials with no axis objects, making a total of 512 trials. Trials were presented in a randomized order. The experiment used a within-subjects design. All the pictures were hand-drawn and transformed to electronic format by a computer scanner. The pictures where edited by the picture editor "Corel Photo-Paint"™and resized to 150x150 pixel format in order to control important factors such as "center-of-mass" and "proximity" which have been shown to affect the appropriateness of spatial prepositions in past studies (Regier & Carlson, 2001). The pictures were black and white and the level of brightness was the same for every picture. The stimuli were presented using the experiment generator E-prime™.

Procedure

Participants had to judge the appropriateness of a spatial preposition (*above, below, over or under*) to describe scenes in an acceptability rating task picture. A sentence was shown before the scene and with the following form; <<the LO is *preposition* the RO>>. The description remained on the screen until participant read the sentence and press the space bar. After the sentence, a picture appeared illustrating a spatial configuration of the objects in the sentence. When ready, participants gave their judgment by pressing a number between 1 and 9 (where 1 = not at all acceptable and 9 = perfectly acceptable). Once the judgment was inserted, the two objects disappeared and the new trial began. This sequence of events is illustrated in Figure 3.3. All trials showed the located object in a "good" or "acceptable" location, never in a "bad" location (Carlson-Radvansky & Logan, 1997). For example in the *above* trials the LO was always shown above the RO horizon. All the trials were presented in a randomized order. The experiment

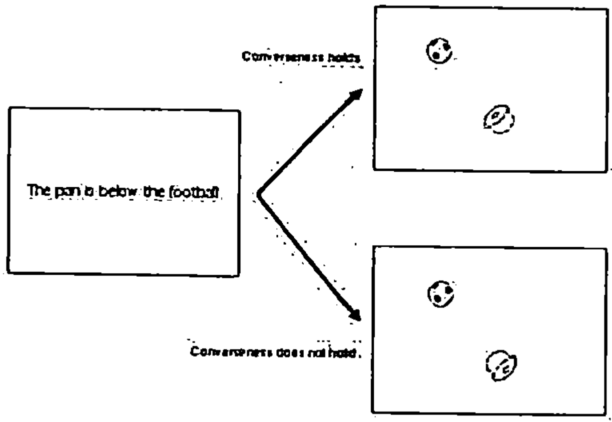

Figure 3.3: Here is illustrated an example of what participants experienced on the trials: a sentence first followed by the target scene. The scene above-right illustrates an example where converseness holds and below-right where it does not.

used a within-subject design. All the pictures were hand-drawn and transformed to electronic format by a computer scanner.

3.2.3 Results

Table 1 reports the mean acceptability ratings and standard deviations (collapsed by side) for trials with the IA objects only. Below we report two separate analyses, one for the "upside-down" and "vertical" orientations, and one for the "pointing at" and "pointing away" orientations. This was done given that the "pointing at/pointing away" manipulations are dependent on the location of LO while the canonical and upside down manipulations are not. Therefore acceptability ratings were submitted to two separated 2 (superior/inferior prepositions) x 2 (preposition set) x 2 (far and near locations) x 2 (orientations) repeated mea-

Table 1
Mean acceptability ratings (and standard deviations) as a function of LO orientation, spatial preposition and proximity in Experiment 1.

Spatial Preposition X Distance		ORIENTATION OF THE LO Vertical	Upside	Pointing at	Pointing away
ABOVE					
	Far	5.9 (1.94)	5.47 (2.04)	5.25 (2.04)	5.48 (2.12)
	Near	6.89 (2.25)	6.47 (2.21)	6.39 (2.11)	6.71 (2.15)
BELOW					
	Far	5.25 (1.56)	5.13 (1.9)	5.09 (1.85)	4.91 (1.82)
	Near	6.48 (1.99)	6 (2.08)	6.3 (2.07)	6.23 (1.96)
OVER					
	Far	4.57 (2.09)	4.38 (2.1)	4.31 (2.02)	4.76 (2.07)
	Near	6.24 (2.18)	5.78 (2.27)	5.82 (2.18)	6.23 (2.2)
UNDER					
	Far	4.88 (1.63)	4.57 (1.89)	4.66 (1.66)	4.4 (1.75)
	Near	5.91 (2.16)	5.86 (2.08)	6.04 (2.04)	5.75 (2.02)

sures ANOVAs. An alpha level of $p < .05$ was adopted unless otherwise specified, and where follow-up analysis are reported, LSD tests were used. For the complete results from the 4-way ANOVA, see Table 9-A in Appendix C.

In the first analysis we included "vertical" vs. "upside down" orientations. There were significant main effects of preposition set ($F(1,31) = 17.27$, $MSE = 58.13$, $p < .0001$), of superior/inferior prepositions ($F(1,31) = 9.4$, $MSE = 5.24$, $p < .01$), and of proximity ($F(1,31) = 56.92$, $MSE = 180.31$, $p < .0001$). Overall, higher acceptability ratings were found for *above/below* ($M = 5.94$) than for *over/under* ($M = 5.27$), ratings were higher overall for superior (*over/above*, $M = 5.71$) than for inferior prepositions (*under/below*, $M = 5.5$), and ratings were higher for scenes where the LO and RO were near ($M = 6.2$) rather than far from each other ($M = 5.01$).

However, there were also interactions between these variables. There was a

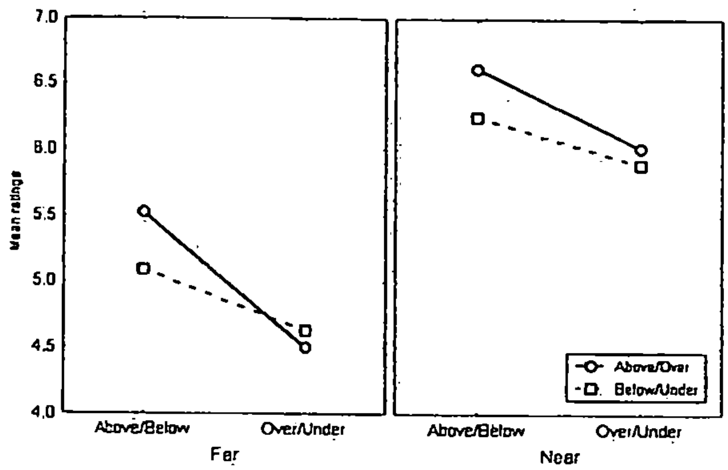

Figure 3.4: The 3-way interaction between preposition set and spatial prepositions.

significant two-way interaction between preposition set and proximity (F(1,31) = 9.01, MSE = 3.41, p < .01), a significant interaction between superior/inferior and prepositions set (F(1,31) = 5.81, MSE = 9.07, p < .05) and a three-way interaction between preposition set, superior/inferior prepositions and proximity (F(1,31) = 8.12, MSE = 1.48, p < .01). This interaction is displayed in Figure 3.4. The effect of proximity was present for all four prepositions (all p < 0.001), but while the difference between superior-inferior prepositions was present for *above* versus *below* for both levels of proximity (p < .0001), for *over* and *under* the difference was significant for near positions only (p > 0.05). No other effects were found.

In the second analysis we compare "pointing at" and "pointing away" orientations. Acceptability ratings were submitted to a 2 (superior/inferior prepositions) x 2 (preposition set) x 2 (far and near locations) x 2 ("pointing at/pointing away") repeated measure ANOVA. For the complete results, see Table 9-B in Appendix C. There were significant main effects of preposition set ($F(1,31) = 10.88$, MSE = 38.91, $p < .01$), of superior/inferior prepositions ($F(1,31) = 8.16$, MSE = 5, $p < .01$), and of proximity ($F(1,31) = 89.15$, MSE = 224.79, $p < .0001$). Overall, higher acceptability ratings were found for *above/below* (M = 5.79) than for *over/under* (M = 5.24), ratings were higher overall for superior (*over/above*, M = 5.61) than for inferior prepositions (*under/below*, M = 5.42), and ratings were higher for scenes where the LO and RO were near (M = 6.18) rather than far from each other (M = 4.85).

Of most interest were effects involving orientation of the LO. To begin with, there was a main effect of orientation of the LO ($F(1,31) = 5.16$, MSE = 0.77, $p < .05$). Overall, sentences were rated as better descriptions for scenes where the LO was "pointing away" (M = 5.55), than scenes where the LO was "pointing at" (M = 5.48, $p < .001$). There were also a two-way interactions between orientation of the LO and superior/inferior prepositions, $F(1,31) = 3.76$, MSE = 8.76, $p = .048$. This interaction, displayed in Figures 3.5, indicates that, accordingly to our predictions, the effect of orientation of the LO does not occur uniformly across prepositions. Taking the interaction between orientation and superior/inferior prepositions first, it is clear that the orientation of the LO is affected by whether the LO is positioned higher or lower than the RO. For superior prepositions, highest ratings were given for the "pointing away" orientation scenes (M = 5.8) while lowest ratings were given for the scenes where the located object was "pointing at" (M = 5.44) the reference object. Follow-up analysis revealed that descriptions for scenes where the LO was "pointing away" were given marginally significant higher ratings than descriptions where the LO was shown "pointing at" ($p < .05$). For inferior relations, scene with the LO "pointing at" the RO received higher

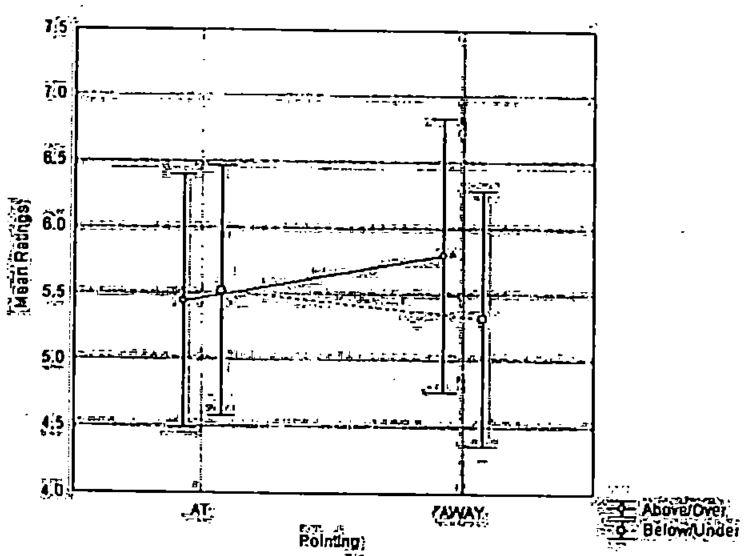

Figure 3.5: The 2-way interaction between orientation effect and superior vs. inferior prepositions.

ratings (M = 5.52) compared to scenes where the LO was "pointing away" from the RO (M = 5.32). Therefore for superior relations, "pointing at" the reference object is associated with lowest ratings, while for inferior prepositions "pointing away" is associated with lowest ratings as expected.

Finally, as many recent guidelines for psycholinguistics have indicated, an item analysis (F2) is often recommended for several reasons. First, a significant result allows generalization from the current set of items to other items drawn from the same population. The second reason concerns the variability between items and specifically items that may cause outliers, which could lead to misinterpretation of significance. This last reason is what Clark (1973b) called "the language-as-fixed-effect fallacy" and the author proposed a solution which requires running an F2 (item analysis) in addition to the F1 (participants analysis) and to calculate minF' that is a generalization at the same time across participants and items. This solution however, has been criticised by Smith (1976) and Wike and Church (1976) for being too conservative. In addition it is has been claimed that item analysis itself it is problematic (Raaijmakers, 2003; Raaijmakers, Schrijnemakers & Gremmen, 1999) given that many experiments do not contain many sets of items (as the case in our experiment) and therefore represent very low statistical power. Therefore in accordance with this view we do not report F2 analyses for the rest of the thesis.

3.2.4 Discussion

The results of the first experiment indicate that the orientation of the LO does affect the appropriateness of a spatial expression to describe a given scene. For *over* and *above*, when the LO is pointing at the RO ratings for these prepositions were significantly lower than when the LO was pointing away from the RO. For *under* and *below* ratings were significantly lower when the LO was pointing away from the LO compared to the condition where the LO was pointing at the RO. In other words, when converseness does not hold, there is an adverse affect on comprehension.

The results also produced a number of results consistent with effects found previously in the spatial language literature. There were strong effects of proximity of the LO to the RO, with near locations rated higher than far locations (consonant with the spatial templates proposed by Logan & Sadler, 1996). Furthermore, the range of regions that is deemed acceptable for superior terms is wider than for inferior terms, hence ratings overall are higher for superior terms than for inferior terms. This difference can be explained in terms of plausibility: Usually bigger objects offer support to little objects rather than the opposite.

Thus is more likely to see a table holding a book than a book holding a table. Regarding the effect of converseness it would appear that the orientation of the LO matters when making a judgement about the appropriateness of a sentence containing *over/under/above/below* to describe where an object with an intrinsic axis is in relation to a RO. However in this experiment the RO was an object without an intrinsic axis (NA). We therefore needed to establish that the effect is robust across a wider range of reference objects.

3.3 Experiment 2

3.3.1 Introduction

The second experiment had two aims. First, we wanted to determine whether the orientation of LO effect observed in Experiment 1 can be generalised across a range of ROs (the RO in Experiment 1 was always a football). This was important to rule out the possibility that the orientation of the LO is used as a cue to the orientation of the whole scene. Second, we set out to test whether the size of the orientation of LO effect found in Experiment 1 changes as a function of the type of RO used. If the RO has a clear oriented (intrinsic) axis we suspected that flouting of converseness would be more extreme as breaking converseness occurs within the same type of reference frame than when flouting occurs in different reference frames (as in Experiment 1). Therefore Experiment 2 employed different types of objects as RO; Intrinsic Axis Object (IA), Non Directional Axis Object (NDA), and No Axis Object (NA)

3.3.2 Method

Participants

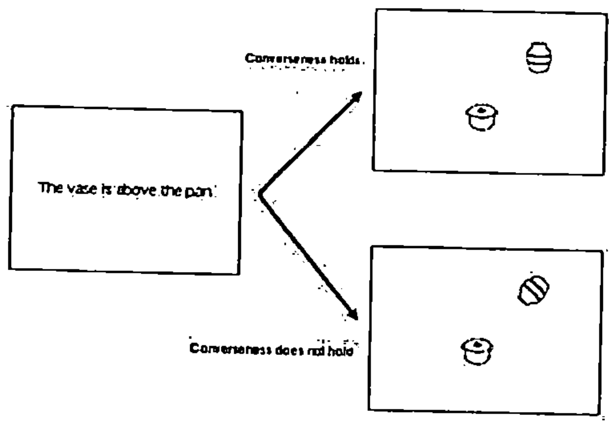

Figure 3.6: Here is illustrated an example of the sequence of events for Experiment 2: a sentence was shown first followed by the target scene. The scene above-right illustrates an example where converseness holds and below-right where it does not.

Twenty-four undergraduate students (19 females and 5 males; age range from 18 to 27, mean age = 19) participated in this investigation for course credit. All the participants were English native speakers and did not take part in any of the previous experiments.

Design and Materials

The methodology employed was essentially the same as that used in Experiment 1, the only difference being that we used three different types of object as ROs: 8 oriented axis objects, 8 non-oriented axis objects and 8 no axis objects. The IA and NDA objects were the same as those used in Experiment 1. We created 8 new no axis objects (including a port hole and a circular shield; see Appendix A for a full list of materials).

The LOs were always oriented axis objects. See Figure 3.6 for an example of trial. The experiment comprised the following variables: 2 (superior/inferior prepositions) x 2 (preposition sets) x 2 (proximity) x 4 (orientations of the LO) x 3 (types of RO: oriented axis objects, non-oriented axis objects and no axis objects) x 8 sets of materials resulting in a subtotal of 384 trials (as preposition set was a between subjects variable in this experiment: all the other variables were within subjects). Half the pictures showed the LO to the right of the RO and half showed the LO to the left of the RO. In addition there were an additional 192 trials where the LO was in the central location, making a total of 576 trials. Orientations and locations of the LO were the same as those used in Experiment 1, and again the central location was included only for design completeness but not included in the data analysis. The RO was always canonically oriented (for the oriented axis and non-oriented axis objects).

Procedure

The procedure was the same as that used in Experiment 1.

3.3.3 Results

The mean acceptability ratings and standard deviations (collapsed across side) for combinations of LO and RO are reported in Table 2.

As for the previous experiment, two separate ANOVAs were carried out in order to separate the effects of the orientation of the LO in scenes where the LO was *above* the RO and scenes where the LO was *below* the RO. In the first analysis acceptability ratings were submitted to a 2 (preposition set) x 2 (superior/inferior prepositions) x 2 (proximity) x 2 (orientations of the LO; "vertical" vs. "upside down") x 3 (type of RO) mixed ANOVA, with repeated measures on the last four

Table 2
Mean acceptability ratings (and SDs) as a function of preposition, proximity and orientation of LO in Experiment 2. The top panel shows the data for trials there the ROs had an Oriented Axis, the middle panel shows the data for Non-oriented axis objects and the bottom panel shows the data for trials where the ROs did not have an axis.

Spatial Preposition X Distance		Oriented Axis Objects as ROs			
		Vertical	Upside	Pointing at	Pointing away
ABOVE	Far	5.69 (1.56)	4.80 (1.88)	4.83 (1.77)	5.06 (1.62)
	Near	7.06 (1.1)	6.18 (1.5)	6.48 (1.4)	6.89 (1)
BELOW	Far	5.25 (1.73)	4.72 (1.66)	4.78 (1.82)	4.92 (1.62)
	Near	7.08 (1)	6.17 (1.4)	6.72 (1.1)	6.24 (1.4)
OVER	Far	4.39 (2.21)	4.08 (1.97)	4.38 (2.1)	3.94 (1.98)
	Near	6.57 (1.7)	6.37 (1.8)	6.01 (1.8)	6.75 (1.5)
UNDER	Far	4.12 (1.86)	3.85 (2.03)	4.02 (1.84)	3.86 (1.87)
	Near	6.20 (1.8)	5.95 (1.8)	6.29 (1.7)	5.94 (2)
		Non-oriented Axis Objects as ROs			
		Vertical	Upside	Pointing at	Pointing away
ABOVE	Far	5.68 (1.6)	4.93 (1.8)	4.94 (1.7)	5.22 (1.7)
	Near	7.05 (.09)	6.16 (1.7)	6.41 (1.7)	6.63 (1)
BELOW	Far	5.22 (1.6)	4.94 (1.7)	5.14 (1.7)	4.73 (1.6)
	Near	6.65 (1)	6.27 (1.7)	6.51 (1.3)	6.34 (1.6)
OVER	Far	4.04 (1.9)	3.97 (2.2)	4.16 (2)	4.31 (2)
	Near	6.11 (1.8)	5.68 (2.2)	6.03 (1.8)	6.43 (1.7)
UNDER	Far	4.04 (2.2)	4.15 (2)	4.16 (2.1)	3.66 (1.9)
	Near	6.06 (1.8)	5.66 (1.9)	6 (1.9)	5.73 (2.1)
		No Axis Objects as ROs			
		Vertical	Upside	Pointing at	Pointing away
ABOVE	Far	5.47 (1.6)	4.91 (1.6)	5.04 (1.8)	5.24 (1.7)
	Near	7.09 (1.07)	6.21 (1.6)	6 (1.71)	6.85 (1.25)
BELOW	Far	5.08 (1.5)	4.75 (1.8)	5.01 (1.9)	4.78 (1.7)
	Near	6.51 (1.31)	6.07 (1.64)	6.56 (1.51)	5.99 (1.97)
OVER	Far	4.34 (1.9)	4.11 (2.1)	4.44 (2.3)	4.83 (2.5)
	Near	6.49 (1.43)	5.98 (1.87)	5.93 (2.18)	6.75 (1.7)
UNDER	Far	4.01 (1.9)	3.71 (1.7)	4.28 (2.3)	3.66 (2)
	Near	6.26 (1.71)	5.87 (1.88)	6.4 (1.65)	5.74 (2.03)

variables (the complete ANOVA results can be found in table 10-A in appendix C).

Significant main effects were found for superior/inferior prepositions ($F(1,22) = 17.41$, $MSE = 5.35$, $p < 0.001$), and proximity ($F(1,22) = 68.81$, $MSE = 432.14$, $p < 0.0001$), for prepositions set ($F(1,22) = 5.51$, $MSE = 82.63$, $p < 0.05$) and for the orientation of the LO ($F(1,22) = 8.67$, $MSE = 32.17$, $p < 0.01$). Consistent with the results of Experiment 1, superior prepositions overall were given higher ratings ($M = 5.56$) than inferior prepositions ($M = 5.33$), and ratings were higher for scenes where the LO and RO were near ($M = 6.32$) rather than far from each other. In addition scenes with the LO in a canonical orientation received higher ratings ($M = 5.69$) than scene where the LO was upside-down ($M = 5.2$) and the preposition *above-below* were overall more acceptable ($M = 5.83$) than the spatial term *over-under* ($M =5.07$).

The analysis also revealed a significant interaction between proximity and the orientation of the LO ($F(1,22) = 6.34$, $MSE = 1.86$, $p < .05$). Proximity effects were found across all the orientation of the LO (all $p < .05$). Specifically, when the LO was near the RO, ratings were higher for the LO in a vertical orientation ($M = 4.78$) compare to the LO upside-down ($M = 4.4$). Similarly, when the LO was far from the RO ratings were higher for the LO in a "vertical" orientation ($M = 6.61$) compare to the LO "upside-down" ($M = 6.02$). This interaction is displayed in Figure 3.7. None of the other interactions were significant.

The second ANOVA focused on the LO orientations "pointing at" and "pointing away" whereas the other variables were the same as those included in the previous analysis. The acceptability ratings were thus submitted to a 2 (preposition set) x 2 (superior/inferior prepositions) x 2 (proximity) x 2 (orientations of the LO; pointing at vs. pointing away) x 3 (type of RO) mixed ANOVA, with

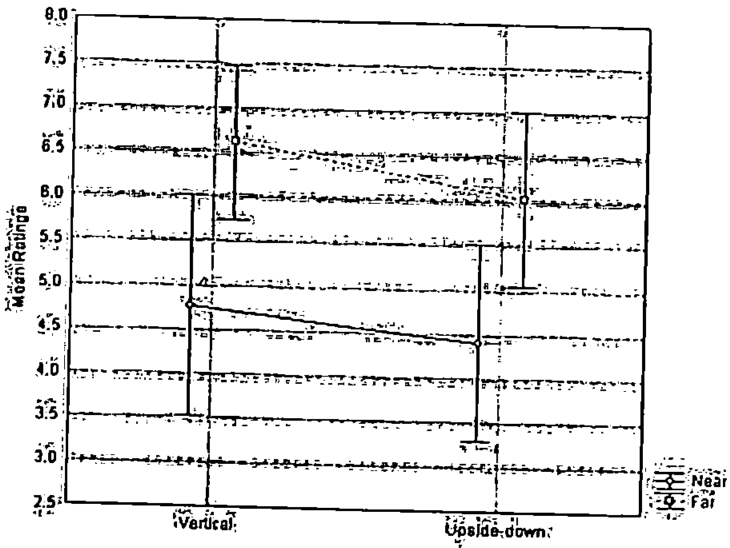

Figure 3.7: This figure shows the 2-way interaction between orientation of the LO and proximity.

repeated measures on the last four variables (the complete ANOVA results can be found in table 10-B in appendix C).

Significant main effects were found for superior and inferior preposition ($F(1,22) = 12.93$, $MSE = 49.99$, $p < 0.0001$) and for proximity ($F(1,22) = 64.9$, $MSE = 451$, $p < 0.001$). As in the previous analysis, superior prepositions overall were given higher ratings ($M = 5.57$) than inferior prepositions ($M = 5.31$), and ratings were higher for scenes where the LO and RO were near ($M = 6.32$) rather than far from each other ($M = 4.55$). We also found a significant interaction between RO types and proximity ($F(2,44) = 4.26$, $MSE = 1.26$, $p < .05$) and between superior-inferior preposition and the orientation of the LO ($F(1,22) = 5.31$, $MSE = 19.19$, $p < .05$).

Finally the analysis revealed two significant 3-way interactions. The first one concerns the proximity, superior-inferior prepositions and orientation of the LO ($F(2,44) = 3.78$, $MSE = 1.25$, $p < .05$). For all types of objects near locations were given higher ratings than far locations. In particular when the objects was shown at far locations and superior spatial preposition were tested, higher ratings were found for scene with the RO was a NA object ($M = 4.89$) compare to the the scene in which the RO was a NDA objects ($M = 4.65$) or a IA object ($M = 4.54$). However none of these comparisons was significant in the post-hoc test. Same pattern was found for inferior preposition. On the other hand, when the LO was placed near to the RO and superior prepositions tested, higher rating were found for IA objects ($M = 6.52$), followed by NDA objects ($M = 6.43$) and NA object ($M = 6.38$). Similar pattern was found for inferior prepositions where higher rating were found for IA objects ($M = 6.29$), followed by NA objects ($M = 6.17$) and NDA object ($M = 6.14$). Follow up analysis revealed that none of these comparisons was significant.

The second interaction, illustrated in Figure 3.8, involved superior-inferior prepositions, type of the RO and orientation of the LO ($F(1,22) = 6.03$, $MSE = 3.17$, $p < .05$). This interaction showed similar results as the second ANOVA in Experiment 1. For *above/over* ratings were lower when the LO "pointed towards" the RO than when the LO was "pointing away" from the RO for all types of RO, and for inferior preposition ratings were lower when the LO pointed away from the RO than when the LO pointed towards the RO. However, post hoc test revealed that the only significant difference between the "pointing at" (superior preposition, $M = 5.35$; inferior prepositions, $M = 5.56$) and the "pointing away" condition (superior preposition, $M = 5.92$; inferior prepositions, $M = 5.04$) was for the scene with NA object ($p < .05$).

Finally we also found a 4-way interaction between RO types, superior-inferior

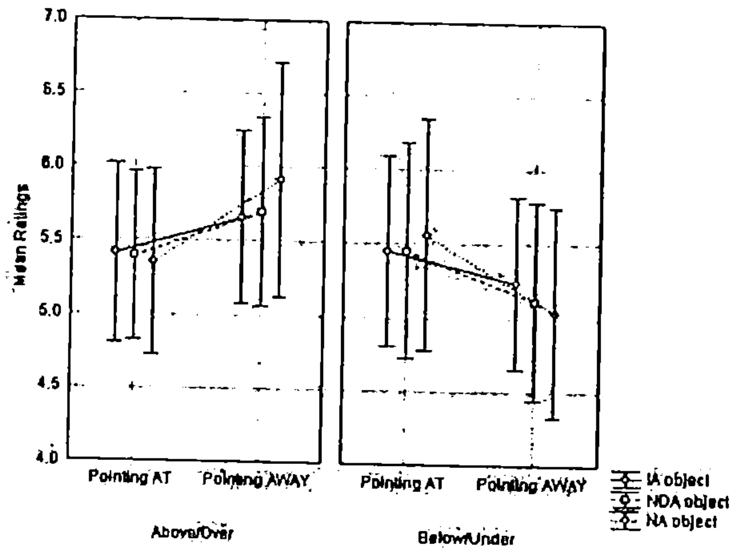

Figure 3.8: This figure shows the 3-way interaction between orientation of the LO, superior inferior preposition and types of RO.

prepositions, proximity and orientation of the LO (F(2,44) = 7.11, MSE = 1.05, p < .001). In order to assess whether orientation of LO effects were present for all three types of reference object, three separate four-way ANOVAs were run, one for each of the RO types. The new analysis revealed a significant interactions involving orientation of LO and superior/inferior prepositions for the RO as NDA (F(1,22) = 4.64, MSE = 5, p < .05) and NA objects (F(1,22) = 5.84, MSE = 14.2, p < .05) illustrating the same pattern found already in the main analysis. For the AI condition the interaction was only marginally significant (F(1,22) = 3.3, MSE = 2.5, p = .08). We also found three way interactions between proximity, superior/inferior prepositions and orientation of the LO for the condition with the IA objects (F(1,22) = 12.18, MSE = 3.6, p < .01) and NA objects (F(1,22) = 5.22, MSE = 1.6, p < .05). None of the other interactions were significant.

3.3.4 Discussion

Experiment 1 found an orientation effect of the LO on the acceptability of a given spatial term when the RO does not have an intrinsic axis. Experiment 2 shows that this effect is present across a range of ROs. The effect of the orientation of the LO is as strong for No Axis ROs as it is for Non Directional Axis ROs and almost as for Intrinsic Axis ROs. This is important for two reasons. First, it could be argued that the explanation of this effect when the RO does not have a salient axis is that there is some doubt regarding the orientation of the whole scene vis-à-vis the absolute frame. Moreover, the fact that the interactions involving orientation of LO and superior-inferior prepositions are present even when the RO has an oriented (intrinsic) axis shows that this is not the case. Second, we speculated that the orientation of LO effect might be stronger when the intrinsic frame was available for the RO as converseness would apply using the same reference frame type. The data did not support this prediction. The results indicate that the orientation of the LO affects comprehension irrespective of the RO type, and therefore irrespective of the extent to which the intrinsic or relative frames are activated on the RO. In the next experiment we explore the possible interaction between LO reference frame(s) and RO reference frame(s), manipulating the orientation of both objects.

3.4 Experiment 3

3.4.1 Introduction

Experiments 1 and 2 provide support for the view that converseness is an important constraint in spatial language understanding. The data suggest that vertical spatial prepositions are regarded as less appropriate to describe a given scene where converseness does not hold compared to scenes where converseness does hold because this generates more situations (states of the world) and this accordingly to Bar-Hillel (1964), will result as being less informative. But does such an effect only occur when processing of reference frames for the RO is easy? This experiment set out to test whether the effect only occurs when there is no cost associated with processing reference frames for the RO (i.e., when the RO is canonically oriented). When there is a conflict between *above* in the intrinsic and *above* in the relative/absolute frame, we were interested to establish whether the orientation of LO effect is diminished. In this experiment we manipulated the orientation of both the LO and the RO at the same time, thus allowing us to dissociate reference frames to establish whether the effect still occurs under increased processing load. Furthermore manipulating the orientations of both LO and RO also allowed us to test a possible alternative explanation for the effect. In Experiments 1 and 2 people judged the scenes where the reference frames for the RO and LO were discordant with lower ratings. Thus a possible alternative explanation for the effect is that the extent to which the reference frames for the RO and LO are aligned affects comprehension. If this is the case, then there should be an interaction between orientation of LO and orientation of RO such that ratings should be higher when the orientation of the LO matches the orientation of the RO and ratings should be lower when orientations mismatch.

3.4.2 Method

Participants

Twenty-five students (21 females and 4 males; age range from 18 to 53, mean age = 21) participated in this study for course credit. All the participants were

English native speakers with normal or corrected to normal vision who had not taken part in any of the previous experiments.

Design and Materials

The variables involved in this study were the following; 2 (superior/inferior prepositions: *above* versus *below*) x 2 (proximity) x 4 (orientations for the LO) x 4 (orientations for the RO). We used just two prepositions in this experiment given the significant increase in the number of trials through the manipulation of the orientation of both LO and RO. There were 8 sets of materials, and half the sets showed the LO to the left of the RO and half showed the LO to the right of the RO, making a subtotal of 512 trials. In this experiment we used slightly different orientations than those used in the previous experiments as we were manipulating the orientations of LO and RO within the same experiment. We used "vertical", "pointing at", "90° facing away" (pointing away from the RO or LO on the horizontal plane) and "90° facing towards" (pointing towards the RO or LO on the horizontal plane). Thus we kept the canonical orientation and the "pointing at" levels of orientation from the previous experiments which exhibited the biggest differences between levels of orientation of LO, and we added the 90° positions so as to be consistent with orientations used in past experiments that manipulated the orientation of the RO (Carlson & Logan, 2001; Carlson-Radvansky & Irwin, 1994). As for the previous experiments separate predictions can be made depending on the orientation and the relative position of the LO respect to the RO. In this experiment the only orientation that depends critically on the relative location of the objects and therefore on the spatial prepositions is the "pointing at" orientation (see an example in Figure 3.9). This has been compared to the orientation that is spatial relation independent: the "vertical" orientation. The

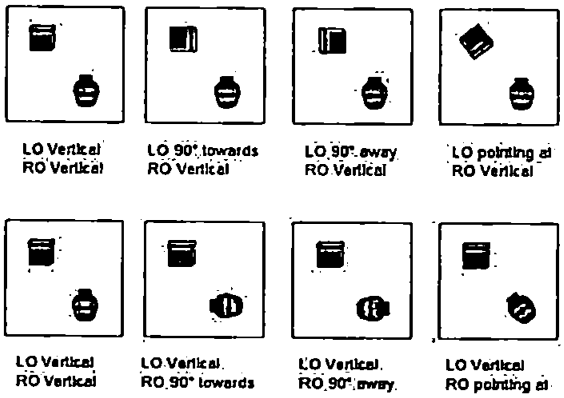

Figure 3.9: This figure illustrate scenes with a combination of orientations for the LO (the box) and the RO (the vase). In the experiment the orientations of both the objects were manipulated at the same time.

other two orientations also depend on the relative location of the object but no interaction with the superior/inferior preposition is expected because it is difficult to identify exactly the cases where converseness holds and where it does not and therefore they will be analysed separately. The central location was not included in the design for the same reason illustrated in the previous experiments but we included 64 more trials in the central location for completeness. In addition we added 48 fillers with non-oriented axis objects and no axis objects, thus each participant saw 624 trials in total. The objects employed in the experiment were the same pictures used for the previous experiment; Intrinsic Axis Object, Non Directional Axis Object, No Axis Object. However Non Directional Axis objects and No Axis objects were treated only as distractors because we have already shown that different objects types did not affect comprehension, and obviously orientation cannot be manipulated for these objects.

Procedure

The procedure was the same as that used for Experiments 1 and 2, with the only difference that the LO could appear in a "good", "acceptable" or "bad" area. For example, if the sentence was <<The vase is *above* the box>> the scene could show the box also below the vase which is in a "bad" area. This manipulation has been introduced in line with the standard procedure used in previous experiments in which the orientation of the RO was manipulated (Carlson-Radvansky & Logan, 1997) and it should only emphasise the differences between low and high acceptability compared to previous experiments.

3.4.3 Results

The analysis focused on the intrinsic axis objects (IA) only and on the positions of the LO that were in good or acceptable regions (thus excluding trials where for example *above* is appropriate in the intrinsic frame but not in the relative frame). So we focused on [+ relative + intrinsic] and [+ relative − intrinsic] frames in order to establish whether conflict between the intrinsic and relative frames affects the orientation of LO effect found in the previous experiments. Table 3 reports the mean acceptability ratings and standard deviations (collapsed by side) for combinations of LO and RO. In the first analysis the acceptability ratings were submitted to a 2 (superior/inferior prepositions: *above* versus *below*) x 2 (proximity) x 2 (orientations of the LO) x 2 (orientations of the RO) repeated measures ANOVA. Given that the orientation "pointing at" depends on the position of the LO respect to the RO and vice versa, this has been analysed separately together with the "vertical" orientation. This comparison is critical for the hypothesis we aim to test.

Table 3
Mean acceptability ratings (and SDs) for combinations of the RO and LO in Experiment 3. The RO and the LO were always objects with an oriented axis.

Spatial Preposition X Distance X LO Orientation			RO Orientation			
			Vertical	Towards	Away	Pointing at
ABOVE						
	Far					
		Vertical	6.92 (1.63)	6.58 (1.95)	5.8 (2.52)	6.86 (1.75)
		Towards	6.11 (2.04)	6.4 (1.75)	5.77 (2.36)	6.25 (2.06)
		Away	6.6 (1.67)	6.8 (1.76)	6.25 (2.1)	6.45 (1.86)
		Pointing at	6.17 (1.86)	6.52 (1.9)	5.98 (2.17)	5.98 (1.95)
	Near					
		Vertical	7.19 (1.88)	7.21 (1.76)	6.86 (1.91)	7.21 (1.52)
		Towards	7.06 (1.84)	7.02 (1.76)	6.03 (2.69)	7.1 (1.22)
		Away	7.1 (1.67)	7.15 (1.77)	6.8 (1.98)	7.13 (1.74)
		Pointing at	6.77 (1.85)	6.76 (2.09)	6.23 (2.51)	6.8 (2.05)
BELOW						
	Far					
		Vertical	6.8 (1.75)	5.9 (2)	6.3 (1.9)	5.8 (2.03)
		Towards	6.48 (1.74)	5.9 (1.92)	6.33 (1.84)	5.78 (2.28)
		Away	6.5 (1.52)	5.9 (2.42)	5.8 (2.07)	5.53 (2.31)
		Pointing at	6.65 (1.95)	5.58 (2.11)	6.17 (2.3)	5.9 (1.73)
	Near					
		Vertical	7.45 (1.55)	6.47 (2.21)	7.18 (1.65)	7.05 (1.91)
		Towards	6.56 (2.02)	6.55 (2.02)	7.21 (1.78)	6.6 (2.09)
		Away	6.52 (2.2)	5.96 (2.61)	6.66 (1.95)	6.78 (2.13)
		Pointing at	7.35 (1.7)	6.6 (2.18)	7.18 (1.77)	6.72 (2.04)

The analysis revealed a main effects of proximity ($F(1,24) = 18.52$, MSE = 44.89, $p < .00001$), a main effect of orientations of the RO ($F(1,24) = 6.34$, MSE = 10.24, $p < .01$) and a main effect of LO orientations ($F(1,24) = 10.48$, MSE = 14.44, $p < .01$) (the complete ANOVA results can be found in table 11-A in appendix C). Scene showing the LO near the RO received higher rating (M = 7.05) than scene showing the LO far from the RO (M = 6.38). Scenes where the RO was in the vertical orientation received significantly higher ratings (M = 6.88) then scenes where the RO was pointing away from the LO (M = 6.56). About the orientation of the LO, trials in which the LO was presented vertical received higher acceptability ratings (M = 6.91) than scene where the LO was pointing away from the LO (M = 6.53).

There was also a significant interaction between preposition and orientation of the RO ($F(1,24) = 5.2$, MSE = 10.24 $p < .05$).. For *below*, when the RO was vertical (M = 7.02) ratings were significantly higher than for the the condition where the RO was pointing at the LO as expected (M = 6.38). No difference was found for *above* preposition; in fact in this condition the RO vertical oriented and pointing at the LO have the same orientation (M = 6.74). There was also a significant interaction between preposition.and the orientation of LO ($F(1,24) = 7.19$, MSE = 7.29, $p < .05$). For *above*, ratings for the vertical (M = 7.06) was significantly higher than for the pointing at the RO (M = 6.41). For *below*, there was no difference given that in this condition the LO vertical oriented and pointing at the RO have the same orientation (M = 6.7). This interaction is illustrated in Figure 3.10. None of the other effects or interactions were significant, and critically there were no significant interactions involving orientation of the RO and orientation of the LO.

The second analysis focused on trials where the LO and the RO were oriented

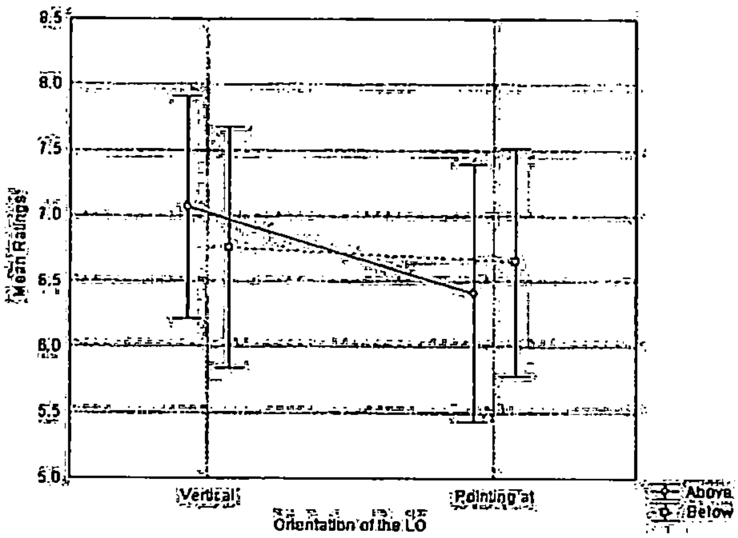

Figure 3.10: This figure shows the 2-way interaction between orientation of the LO and superior inferior prepositions.

of "90° facing away" or "facing towards" each other. In this case there should not be an interaction with superior/inferior spatial preposition. The ANOVA revealed only a main effect of proximity ($F(1,24) = 23.83$, $MSE = 53.66$, $p < .001$). Scene showing the LO near the RO received higher rating ($M = 6.87$) than scene showing the LO far from the RO ($M = 6.13$). No other effect was found.

3.4.4 Discussion

The effects found for the orientation of the RO are consistent with results found previously (Carlson-Radvansky & Irwin, 1994). When the spatial preposition maps onto a good region in both the intrinsic and relative frames ratings are higher than when the preposition is appropriate only within a single reference frame. The effects of the orientation of the LO are also consistent with the results of Experiments 1 and 2. Rotating the LO such that it is pointing at the RO (in this experiment) is associated with lower ratings for *above* than when the LO is vertical, while for *below* no difference was found. The opposite trend was found for the effect of the orientation of the RO; trials where the RO is pointing at the RO (in this experiment) is associated with lower ratings for *below* than when the LO is vertical, while for *above* no difference was found.

Of most interest in this experiment is the absence of an interaction between the orientation of the RO and the orientation of the LO. This addresses two issues. First, this lets us eliminate the hypothesis that the orientation of LO is important by virtue of the degree of alignment of LO and RO. It was possible that any mismatch in orientation of the RO and LO led to participants doubting their reference frame assignment on the RO, and hence to reduced acceptability ratings. This was not the case. Second, the effect of the orientation of the LO occurs even when there is cost associated with the processing of reference frames for the RO. Converseness is important even for scenes where multiple reference frames conflict in the assignment of direction to space, and therefore converseness persists even when the spatial comprehension process is more taxing. Another point to note is that the effect sizes for the orientation of LO and orientation of RO in this experiment were not dissimilar. Given that reference frame assignment is a necessary part of the spatial comprehension process, this provides further evidence that converseness is important for spatial language comprehension.

In summary the findings indicate that the effects of the orientation of the LO is independent of the reference frames adopted for the RO. However, there is one further possible explanation for the effect that we have not thus far considered. Although the effect of the LO is still present when there is cost in processing reference frames for the RO, it could be that cost in identifying the LO when it is rotated affects ratings without requiring the converseness rule at all. Thus far the experiments have used mono-oriented objects, that are objects represented in a viewer-centred frame of reference determined by the location of the object relative to the observer (Tarr & Pinker, 1989) and, as a consequence, naming latencies for these type of objects increase as a function of the angular distance between the orientation of the stimulus and its more familiar upright canonical orientation (Biederman, 2000; Jolicoeur, 1985). Furthermore it is likely that participants rotate these objects to match a familiar orientation automatically (Tarr & Pinker, 1989, 1990). The next chapter will take into account this hypothesis running a further acceptability rating study using objects without increased identification costs at rotation so that identification costs could be accepted or eliminated as an alternative explanation for the effect.

3.5 Summary

This chapter has introduced the first series of experiments on the spatial prepositions *above, below, over* and *under*. Contrary to most findings that have shown that only the orientation of the RO is important for spatial language because it drives the process of assigning the reference frames (Carlson, 1999; Carlson-Radvansky & Irwin, 1994; Logan, 1994; Taylor & Rapp, 2004), the results suggest that people take into account the orientation of the LO as well. The evidence indicates that the orientation of the LO affects the acceptability of sentences containing spatial prepositions in accordance with the hypothesis that scenes where converseness does not hold are less informative. The results also indicate that converseness influences the acceptability of spatial descriptions across all types of reference objects. Converseness has been found even within scenes where multiple reference frames conflict in the assignment of direction to space, and therefore the effect of converseness persists even when the spatial comprehension process is more taxing. However, the results can potentially be explained in terms of cost in identifying the LO when it is rotated without requiring converseness. In order to test this alternative explanation, the next chapter will take into account this hypothesis using objects without identification costs.

Chapter 4

Polyoriented Object Experiments

4.1 Introduction

Recognising new and familiar objects, even under a wide variety of conditions, including recognising changes in color, viewpoint or orientation (so called *object constancy*), is a common activity in every day life. Among the several theories proposed to explain how objects are recognised, there are accounts in support of the idea that object recognition is viewpoint-dependent and theories supporting the hypothesis that object recognition is viewpoint-invariant. Biederman's approach (Biederman, 1987) represents one of the most representative viewpoint-invariant theories, and assumes that objects are represented on the basis of distinctive features[1] and their inter-relations remain constant across changes in perspective. A similar approach is Marr's $2\frac{1}{2}D$ sketch (Marr, 1982). Marr claimed that object recognition derives from constructing a visual representation that provides information about edges and surfaces as defined from the viewer's perspective, and recognition can take place when a 3D object representation is built.

[1]Objects are segregated in primitive geometric objects, the *geons*, that are wedges, cylinders and cones.

Object features are defined with respect to a reference frame centred on the object rather than on the viewer. This object-centred representation allows recognition from various views, because its structure is not affected by rotations and changes in viewing conditions (Marr & Nishihara, 1978). However, the theoretical implications that the time taken to recognise objects depends on the orientation of the stimulus remains the subject of considerable debate (Biederman, 2000; Corballis, 1988; Tarr & Pinker, 1990).

In contrast to viewpoint-invariant theories, viewpoint-dependent theories are based on the fact that recognition often shows a monotonic decrease in performance (as measured by reaction time and/or accuracy) with increasing degree of rotation (Jolicoeur, 1985; Tarr & Pinker, 1989). These theories state that objects are represented in a viewer-centred frame of reference determined by the location of the object relative to the observer. With respect to the nature of the object representation, some theorists believe that representations of objects are stored in a single canonical orientation, while others argue that multiple views are stored, corresponding to different instances encountered during the course of one's experience with the object (Tarr & Pinker, 1989). Shepard and Metzler (1971), in their classical experiment, also measured the time needed to complete a mental rotation showing that people take about 1 sec every 50^o of rotation.

The evidence collected from object recognition experiments suggests that an object's orientation is central in the recognition process and that, according to viewpoint-dependent theories, people take longer to identify objects when rotated. This suggests that showing objects in a non canonical orientations such as those used in the previous experiments, can potentially explain the results illustrated in the previous chapters. In order to exclude this possible confound, we replicate some of the previous experiments using objects that do not show increased recognition time when non canonical orientations are used; these are the so called *polyoriented objects* (Arguin & Leek, 2003; Harris & Dux, 2005a; Leek, 1998a,b).

In Leek's experiments a simple word-picture paradigm was adopted. Participants had to read a name of an object and then decide whether this name matched with the picture that appeared afterwards. All the objects were objects with a clearly defined principal axis of elongation (Intrinsic Axes Objects) and half were polyoriented objects all from the same class (fruit and vegetables, for example apple, pepper, strawberry, etc.) and half were mono-oriented objects. In order to select the most appropriate polyoriented objects Leek required participants to report the incidence with which these objects were found in the natural environment: Objects that had been seen at the highest number of different orientations were chosen as polyoriented objects. The fact that polyoriented objects belong to the same class should not have consequences because there is no reason to believe that fruits representations are stored in a multiple views way and other objects are not. During the experiment the objects were shown with 8 different orientations, from 0^o to 315^o where the 0^o for polyoriented objects was always such that the principal axis of elongation was parallel to the vertical axis of the monitor. The results, summarised in figure 4.1, showed that the time taken to identify line drawings of common mono-oriented objects increases as a function of the angular distance between the orientation of the stimulus and its familiar canonical orientation. In contrast, the time taken to identify common polyoriented objects seems to be independent of their image plane orientation (Leek, 1998b).

Harris and Dux (2005a; 2005b), showed object recognition invariance using both polyoriented and mono-oriented objects in a repetition blindness paradigm.

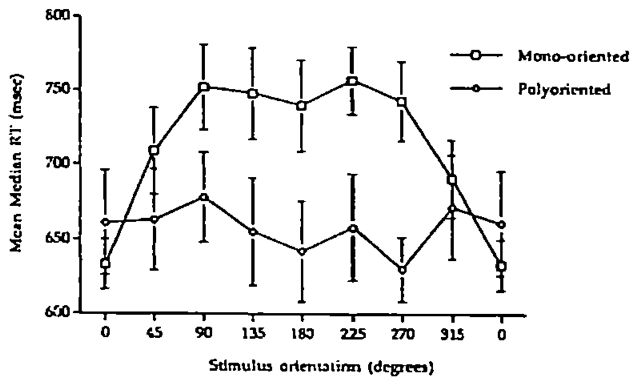

Figure 4.1: Mean median reaction times (RTs) for the mono- and polyoriented objects as a function of stimulus orientation in Leek (1998b). Bars indicate standard error. RTs at the 0^0 orientation are repeated for ease of comparison.

In their experiment the difference between the two objects was the orientation with which they were presented. The authors found a significant repetition blindness for all orientation differences, consistent with the existence of orientation-invariant object representations. However, under some circumstances, this effect was reduced or even eliminated when the repeated object was rotated by 180° both with polyoriented objects that with mono-oriented objects. This suggests that the upside-down orientation is processed more easily than other rotated orientations and that object identity can be determined independently of orientation. In summary, there is evidence that recognition time is not affected by the orientation of poly-oriented objects (Arguin & Leek, 2003; Harris & Dux, 2005a; Leek, 1998a,b); this makes poly-oriented objects perfect to test whether identification costs can potentially explain the results of the previous experiments.

In the next section this hypothesis will be tested using an acceptability rating task and by a sentence-picture verification task. This new paradigm was introduced because establishing whether converseness holds may take some time and, therefore, it may occur only in paradigms without time pressure such as an acceptability rating task. For this reason we decided to use a paradigm that requires participants to give a fast response under time pressure, providing also information on the time course of the converseness effect.

4.2 Experiment 4

4.2.1 Method

Participants

Twenty-seven students (21 females and 6 males; age range from 19 to 26, mean age = 20) from the University of Plymouth participated in this study for credit course. All the participants were English native speakers with normal or correct to normal vision. No participant took part in any of the previous studies.

Design and Materials

This experiment was identical to Experiment 1 with the difference that poly-oriented objects were used rather than mono-oriented objects. These new objects were selected from those used by Leek (1998b) from the same categories of fruit and vegetables[1]. We used polyoriented objects as LO and RO but we manipulated the orientation of LO only. Levels of orientation were the same as those used in Experiments 1 and 2. An example of the stimuli used in this experiment is illustrated in Figure 4.2. The variables in the design (within subjects) were the same as in Experiment 1: 2 (preposition sets) x 2 (superior/inferior prepositions)

[1] We ran a pilot experiment with the selected polyoriented objects in which recognition times were collected. The results replicated those of Leek.

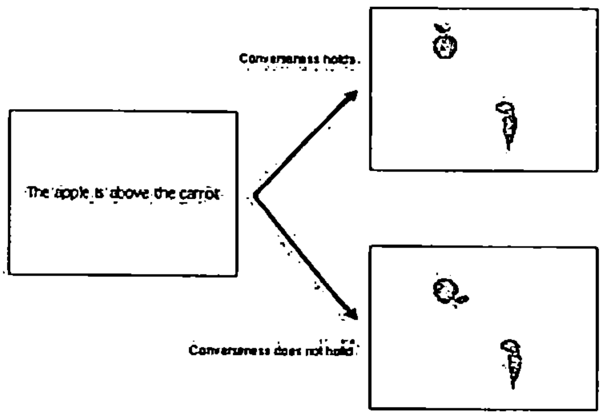

Figure 4.2: This Figure shows an illustration of what participants experienced in Experiment 4. The procedure was the same as that used in the previous experiments. The scene above-right illustrate an example where converseness holds and below-right where it does not.

x 2 (proximity) x 4 (directions of LO), and we included 8 distinct sets of materials. Again we also included 128 scenes where the LO was centrally located and 128 NA objects treated as distractors making a total of 512 stimuli.

Procedure

The procedure was the same as that in Experiment 3

4.2.2 Results

The data were treated in the same way as in Experiment 1, running separate ANOVA for "vertical/upside down" orientations and for "pointing at/pointing away" orientations. Table 4 reports the mean acceptability ratings and standard deviations (collapsed by side) for combinations of LO and RO. The first analysis

Table 4
Mean acceptability ratings (and SDs) as function of LO orientation, spatial preposition and proximity in Experiment 4 (polyoriented objects).

Spatial Preposition X Distance		Vertical	Upside down	Pointing at	Pointing away
ABOVE					
	Far	5.39 (1.93)	5.19 (1.85)	5.05 (1.71)	5.48 (1.75)
	Near	6.84 (1.31)	6.72 (1.51)	6.68 (1.65)	7.01 (1.22)
BELOW					
	Far	6.51 (1.53)	6.36 (1.71)	6.72 (1.48)	6.54 (1.64)
	Near	5.14 (1.88)	5.12 (1.98)	4.86 (1.91)	4.75 (1.89)
OVER					
	Far	4.38 (2.02)	3.99 (1.89)	4.1 (1.85)	4.33 (2.02)
	Near	6.2 (1.86)	6.13 (1.88)	6.03 (1.94)	6.43 (1.79)
UNDER					
	Far	4.35 (1.89)	4.46 (1.91)	4.19 (2.02)	4.02 (1.77)
	Near	6.12 (1.81)	5.86 (1.97)	6.11 (1.89)	6.03 (1.95)

focused on the position invariant orientations thus the variables included were: 2 (superior/inferior prepositions) x 2 (preposition sets) x 2 (proximity) x 2 (orientations of the LO, "vertical" vs. "upside down") repeated measures ANOVA. For the complete results from this ANOVA, see Table 12-A in Appendix C.

There were significant main effects of proximity ($F(1,26) = 64.12$, $MSE = 274$, $p < .0001$) and of preposition set ($F(1,26) = 12.63$, $MSE = 55.4$, $p < .001$), together with significant interactions between proximity and preposition set ($F(1,26) = 12.08$, $MSE = 4.14$, $p < .001$), and between superior/inferior prepositions and proximity ($F(1,26) = 8.49$, $MSE = 2.16$, $p < .01$) all mirroring the pattern of results found in Experiment 1.

There was also a significant three-way interaction between proximity, preposition set and orientation of the LO ($F(1,26) = 4.325$, $MSE = 1.28$, $p < .05$). This interaction is displayed in Figure 4.3. For superior prepositions in far positions

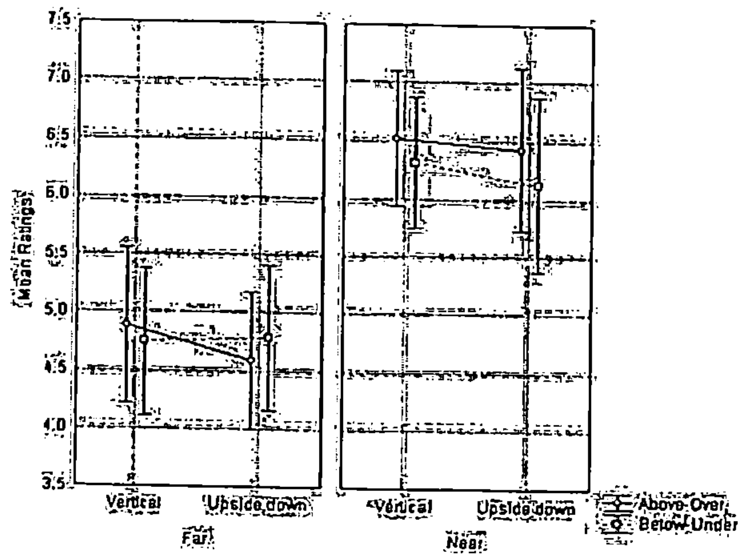

Figure 4.3: The 3 way interaction is here illustrated between superior-inferior preposition, proximity and LO orientation.

vertical (M = 4.88) orientations were rated higher than upside down (M = 4.58) ($p < .01$). For inferior prepositions in far locations, vertical (M = 4.74) orientations were rated lower than upside down (M = 4.82) orientations (n.s.). For superior prepositions in near locations, scenes where the LO was vertical ratings were higher (M = 6.51) than upside down (M = 6.47) (n.s.). Finally for inferior prepositions in near locations, scenes where the LO was vertical received higher ratings (M = 6.41) than upside down orientations (M = 6.12) ($p < 0.01$). No other pairwise differences were found. None of the other main effects or interactions were significant.

The analysis focused on the "pointing at" vs. "pointing away" orientation revealed a main effect for proximity ($F(1,26) = 90.06$, MSE = 376, $p < .0001$), preposition set ($F(1,26) = 13.08$, MSE = 57.9, $p < .001$), superior-inferior prepositions ($F(1,26) = 11.54$, $MSE = 5.93$, $p < .001$) and for the orientation of the LO ($F(1,26) = 7.16$, $MSE = 1.29$, $p < .001$). In the same vein of the previous analyses scenes where the LO was near to the RO received higher ratings (M = 6.44) than scene where the LO was far from the RO (M = 4.59). Again superior preposition were rated as more acceptable (M = 5.63) than inferior prepositions (M = 5.4) and prepositions *above-below* received higher ratings (M = 5.88) than spatial terms *over-under* (M = 5.15). Finally the main effect of the orientation of the LO showed that scenes where the LO was pointing at the RO were less acceptable (M = 5.46) than scenes where the LO was pointing away from the RO (M = 5.57). The analysis also revealed an interaction between preposition set and proximity ($F(1,26) = 7.3$, $MSE = 2.23$, $p < .05$) showing that spatial preposition *above-below* received higher rating in the near location (M = 6.7) than in far locations (M = 5.02) and *over-under* received higher rating in near location (M = 6.2) than in far location (M = 4.28) (all $p < .001$). No other effects were found.

4.2.3 Discussion

The current experiment basically replicated the results of Experiment 1 using polyoriented objects rather than mono-oriented objects. This indicates that the effect of the orientation of the LO is not related to identification costs, but rather to the possibility to apply the converseness. In fact, as in the previous experiment, superior spatial prepositions were rated less acceptable when the LO was upside down and inferior prepositions were rated less acceptable when the LO was pointing away from the RO. We also replicated the proximity effect, with short LO-RO distances being judged as more appropriate then far distances and the overall preference for superior prepositions.

In order to investigate whether converseness affects judgments only in a self-paced experiment such as the acceptability rating task reported above, the next experiment adopted a sentence-picture verification task paradigm using the same polyoriented objects as used in this experiment.

4.3 Experiment 5

4.3.1 Introduction

The empirical evidence obtained in the previous experiments corroborates the hypothesis that informativeness by virtue of the converseness rule affects the spatial apprehension process. However, all of these experiments employed an acceptability rating paradigm. Although that methodology shows that the effect of the orientation of LO is present, such a methodology is not informative regarding the time course of the effect. Establishing whether converseness holds may take some time, and therefore may only occur in tasks which allow responding at leisure. For that reason in Experiment 5 we adopted a sentence-picture verification task paradigm using the same polyoriented objects as used in Experiment 4.

In order to use a sentence-picture verification task methodology, some changes to the design used in the previous experiments were necessary. As Logan and Compton observed (1996), using just two objects in such a paradigm affords the use of strategies by participants and therefore obscures the variables under investigation. In particular, when only two objects are present participants can perform the task successfully by paying attention only to one object in the scene rather than paying attention to the relationship between the LO and RO. For example, if the sentence was "the carrot is *above* the pumpkin", participants could respond simply by processing "the carrot is *above*" and by looking in the top region of the screen (hence disregarding the RO completely). The solution proposed by Logan and Compton, and the one we adopted, was to create scenes with (at least) three objects, in order to force subjects to look at (and process) all three objects before responding.

4.3.2 Method

Participants

Twenty four volunteers (13 female and 11 male; age range from 18 to 56, mean age = 26.69) participated in this study for money. All the participants were English native speakers with normal or correct to normal vision. None of them took part in any of the previous experiments.

Design and Materials

The experiment manipulated the orientation of the LO in the same way as in Experiments 1, 2 and 4 ("vertical", "upside-down", "pointing at" and "pointing away" orientations), as well as using two prepositions as in Experiment 3 (*above* versus *below*). However the addition of a third object (distractor) meant that there were three locations for the LO on the vertical axis (high, middle, and low) with respect to the other two objects (see Figure 4.4 for example scenes) as well as two vertical positions for the RO ("top" and "bottom"). We used 8 objects that were randomly assembled into 8 sets of three objects; so every trial showed a different combination of 3 objects. We included an equal number of true and false trials also, resulting in 96 stimuli which we presented 4 times in order to have enough consistency between trials for a total of 384 stimuli for each participant. Three objects were shown on the screen simultaneously; a RO, a LO (both described in the sentence), and a third distractor object (not mentioned in

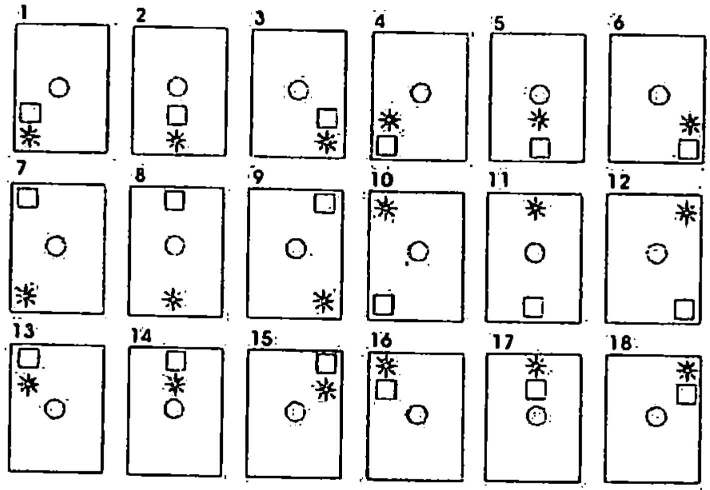

Figure 4.4: This figure illustrates all the combinations of the possible locations for the LO (circle), the RO (square) and the distractor (star).

the sentence) in order to force participants to look at (and process) all the three objects in the scene as recommended by Logan and Compton (1996). The objects were placed in a 3 X 3 point grid (hidden for participants), and both the RO and the distractor could appear in three horizontal locations; left, right and central locations. The RO and distractor were always aligned, that is they appeared in the same vertical locations. Sides were counterbalanced such that half the trials occurred with the LO to the left of the RO and distractor and half occurred with the LO to the right of the RO and distractor. The whole array involving the three objects was also randomly moved around the screen in order to avoid showing the objects always in the same location on the screen. All the objects used in the experiment were the poly-oriented objects used in Experiment 4. Half of the trials were "True" (192) and half "False"; "False" trials were incorrect because the spatial preposition specified in the sentence did not match the spatial relation shown in the scene. For example if the sentence was "the apple is *above* the pumpkin" the "False" scene showed the apple below the pumpkin. The Experiment was programmed and run using E-Prime^{TM}, and responses were recorded by a response box with time accuracy of about 1 ms. We investigated only *above* and *below* in order to keep the experiment within an acceptable duration (30-35 minutes).

Procedure

Each trial began with a sentence that remained on the screen for 2000 ms, followed by a blank screen lasting 100 ms. Subsequently a fixation point appeared in the middle of the screen for 400 ms, followed by another blank screen for 100 ms. Next, the picture containing the three objects appeared for (5000 ms) during which time participants responded. However the picture disappeared when participants pressed the response key. The sequence terminated with a blank screen of 1000 ms, before the next trial began. Participants responded via a button box using the left and right index fingers. The respond keys were labelled "true" and "false", and response mapping was counter-balanced within subjects. Feedback based on the trueness of the responses was provided as well in order to increase the accuracy. The RTs were computed from the picture onset.

4.3.3 Results

Overall 6.21% of the trials involved errors where participants responded TRUE when false or FALSE when true: 54% of these were on true trials and 46% on false trials. Errors were excluded from the subsequent analyses. Correct responses (9561) were "cleaned" with a 2 SD filtering procedure that eliminated 472 outliers (= 4.93%). Three subjects were also excluded because they made

Table 5
Mean latencies (and SDs) from the sentence-picture verification task with polyoriented objects (Experiment 5).

Sentence Value X Spatial preposition X LO location	LO Orientation: Vertical	Upside down	Pointing At	Pointing Away
TRUE				
Above				
Top	1163 (505)	1115 (484)	1134 (492)	1188 (522)
Middle	1459 (507)	1435 (450)	1590 (448)	1450 (474)
Bottom	-	-	-	-
Below				
Top	-	-	-	-
Middle	1555 (581)	1581 (489)	1507 (499)	1519 (521)
Bottom	1315 (574)	1288 (553)	1279 (527)	1205 (525)
FALSE				
Above				
Top	-	-	-	-
Middle	1578 (511)	1552 (489)	1533 (480)	1664 (533)
Bottom	1213 (551)	1185 (544)	1202 (526)	1263 (556)
Below				
Top	1290 (559)	1359 (568)	1382 (527)	1379 (597)
Middle	1672 (552)	1607 (500)	1723 (552)	1685 (556)
Bottom	-	-	-	-

significantly more errors (greater than 30%) than the other participants (who made no more than 3% errors). Below we report the results of analyses of TRUE and FALSE responses separately for positions where the LO and RO were immediately above/below each other (and therefore for scenes where the distractor was positioned either higher or lower than both the RO and LO). Separate analyses were also carried out for "vertical-upside down" orientations and for "pointing at-pointing away" orientations given that these last conditions depend upon whether the LO is *above* or *below* the reference object. Table 5 reports the mean RTs and standard deviations for combinations of LO and RO as a function of position.

Correct True Responses

The data were analysed using a 2 (prepositions: *above* vs. *below*) x 2 ("vertical" vs. "upside down" orientation of the LO) within subjects ANOVA. For

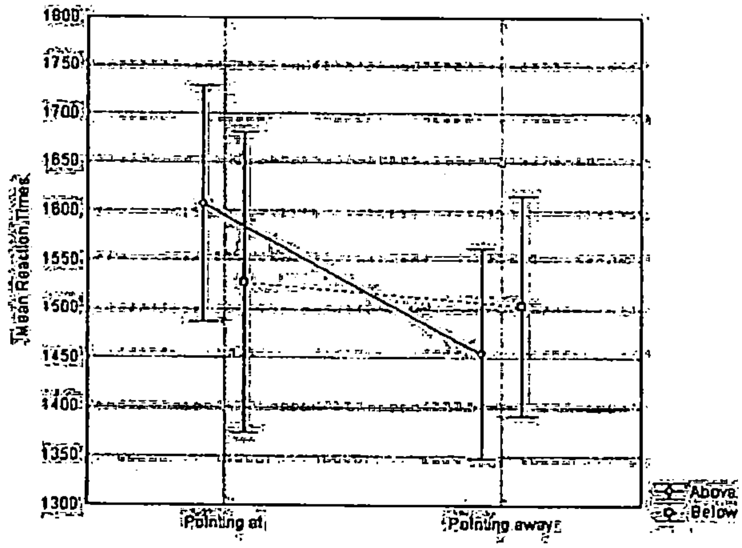

Figure 4.5: The interaction between orientation of the LO and spatial prepositions.

the complete results from the ANOVA, see Table 13-A in Appendix C. This first analysis revealed only a significant main effect for spatial preposition ($F(1,23) = 7.48$, $MSE = 185956$, $p < .05$). The analysis including the orientations "pointing at" and "pointing away" the RO showed a main effect of orientation ($F(1,23) = 6.56$, $MSE = 187076$, $p < .05$) with the scene with the LO "pointing at" the RO were processed slower ($M = 1576$ ms) than scenes with the LO "pointing away" from the RO ($M = 1479$ ms) (for the complete results from the ANOVA, see Table 13-B in Appendix C). We also found a significant interaction between orientations of the LO and spatial prepositions ($F(1,23) = 6.13$, $MSE = 100148$, $p < .05$). This interaction is illustrated in Figure 4.5. The interaction between orientation of the LO and preposition revealed that there were no significant differences between levels of orientation of LO for correct *below* responses: in fact trials where the LO was "pointing at" (M = 1503 ms) or "upside down" (M = 1509 ms) took similar times to respond to trials where the LO was "pointing away" from the RO (M = 1527 ms). For ***above***, the "pointing at" the RO scenes were responded to significantly slower (M = 1607 ms) than "pointing away" from the RO (M = 1455 ms) ($p < .001$).

Correct False Responses

In Table 5 are reported the mean RTs and standard deviations. The data were analysed using a 2 (preposition: ***above*** versus ***below***) x 4 (orientation of the LO) within subjects ANOVA. As for the Correct True analysis, we carried out separate analyses for two group of orientations. In the analysis comparing vertical vs. upside down orientation, no significant effects were found.

The analysis including the "pointing at" and "pointing away" orientations revealed a significant main effect of preposition ($F(1,23) = 10.61$, $MSE = 260000$, $p < .001$). Overall ***above*** trials were faster (M = 1590 ms) than ***below*** trials (M = 1694 ms). The interaction between spatial preposition and orientation of the LO was also significant ($F(1,23) = 11.21$, $MSE = 250000$, $p < .01$). For ***above*** the scenes where the LO was "pointing at" the RO were responded to more quickly (M = 1525 ms) than scenes where the LO was "pointing away" from the RO (M = 1665 ms) ($p < 0.01$). No other differences were found for above trials. For ***below*** trials the quickest responses were for "pointing away" orientations (M = 1658 ms) and the slowest were for "pointing at" (M = 1731 ms) orientations ($p < .01$). No other differences were significant for ***below*** trials.

4.3.4 Discussion

The aim of this experiment was to investigate whether the effect of the orientation of the LO on the acceptability of spatial prepositions to describe given scenes persists under speeded response conditions. The results are consistent with the results found in the previous experiments. For *above* TRUE responses, scenes where the LO was "pointing at" the RO were the slowest and scenes where the LO "pointed away" from the RO were the quickest. For FALSE responses on the same spatial preposition, scenes where the LO "pointed at" the RO were reacted to the quickest and scenes where the LO "pointed away" from the RO responses were the slowest. These results are consistent with the notion that converseness matters even under time pressure for superior relations.

The lack of effects for "vertical" and "upside down" orientations indicates a strong axial effects overall but the effect of "pointing at" and "pointing away" orientations for *above* and *below* using a speeded respond paradigm are consistent with those of previous experiments.

4.4 Summary

In this fourth chapter we had taken into account the alternative hypothesis that the effect of the orientation of the LO in the earlier experiments may be due to identification costs instead of the effects of converseness. For this reason we ran an acceptability rating task and a sentence picture verification task using polyoriented objects, that do not involve identification costs (Leek, 1998b). The results from both experiments exclude this alternative explanation and corroborate the hypothesis that people apply converseness in order to construct the most informative spatial model from a given scene and such a model is the one which supports the strongest inferences about the situation that are consistent with the information present in the scene itself. In the same vein, in the next chapter we will investigate whether our hypothesis can be applied to other projective spatial prepositions that involve the horizontal axis instead of the vertical axis: *on/to the left/right, in front of* and *behind.*

Chapter 5

Other Projective Prepositions: *In front of, Behind, On the left/right, To the left/right*

5.1 Introduction

In the previous chapters we presented evidence in support of the hypothesis that people draw inferences with regards to spatial relations, and in particular those based on the logic of converseness (Levelt, 1996), and those inferences in turn affect the extent to which spatial descriptions are regarded as acceptable to describe those spatial relations. When converseness does not hold the description becomes less informative because in this case the number of states of the world where it is true is higher than cases where converseness does hold. As a consequence, the same description referred to scenes where converseness does not hold is less informative, and the spatial description itself is less appropriate to describe the given scene. This chapter asks whether converseness is also important for other spatial prepositions such as *on/to the left/right* (Experiment 6 and

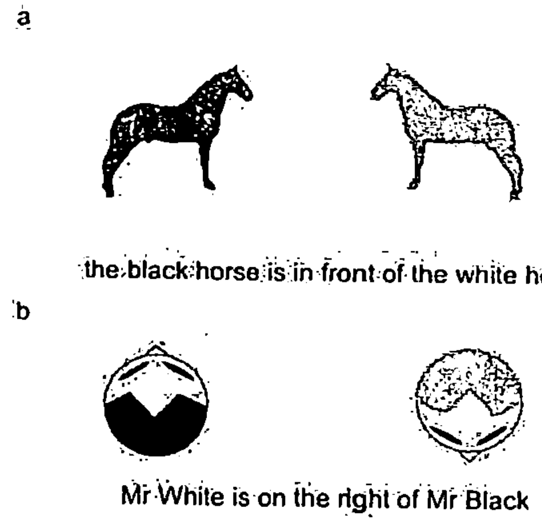

Figure 5.1: In "a" converseness does not hold because both the objects can be described as being *in front of* each other. Following the same logic, converseness does not hold in "b" either.

7) and *in front of/behind* (Experiment 8) that involve different axes from the vertical axes associated with *over, under, above and below* (see Figure 5.1 for an example). We know from literature that the interpretation of spatial terms such as *above* and *below* activates multiple reference frames (Carlson-Radvansky & Irwin, 1994; Carlson-Radvansky & Logan, 1997) where the absolute (gravitational) reference frame is considered by many to be the most influential. However, not all the projective prepositions rely on the gravitational axis but, instead, involve the horizontal dimension where the relative and intrinsic dominate (Levelt, 1984). For example it has been shown that young children, placing an object *in front of* and *behind*, prefer to assign an intrinsic frame on objects with a clear intrinsic axis while a relative reference frame is preferred for non-fronted objects (Harris & Strommen, 1972). In more detail, we expect the spatial prepositions *on/to*

the left and *on/to the right* to be more reliant on the relative frame than the intrinsic frame because in this case the viewer's point of view (relative) is still the most used. On the other hand, the intrinsic frame should be particularly important for the spatial terms *in front of/behind*. Experiment 8 in this chapter focuses on these spatial prepositions in order to investigate whether converseness influences also prepositions that are unaffected by the gravitational plane (that is the absolute reference frame).

5.2 Experiment 6

5.2.1 Introduction

The results from previous experiments support the hypothesis that scenes where converseness does not hold are judged as less acceptable since the communication becomes less informative. However, this decrease in rating could be explained also in a more simple way: The basic interpretation of a spatial sentence is the one in which the LO is in canonical orientation or aligned with the gravitational plane and any deviation from that results in lower acceptability. In other words, participants' judgments may reflect the degree of plausibility or "usualness" of a scene. The current experiment aims to discount this alternative interpretation manipulating converseness whilst showing the objects in canonical orientation. This is made possible using spatial expressions such as *on/to the right* and *on/to the left*. With this experiment we were also interested in comparing the prepositions *on* and *to* that co-occurs with *left/right* in order to investigate the preference for the intrinsic versus the relative frame respectively.

As for *above-below* prepositions, we manipulated the orientation of the LO in order to modify the applicability of converseness (see figure 5.2) and, as a

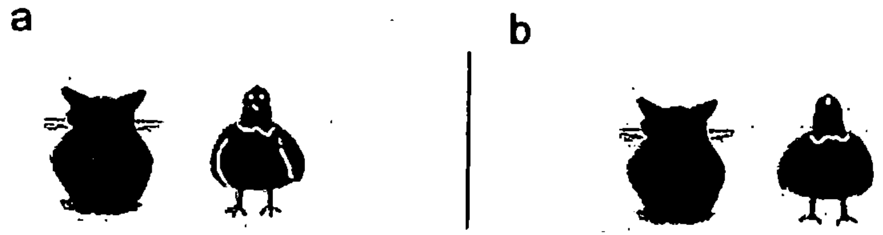

Figure 5.2: Two examples of scene where people have to rate the appropriateness of a sentence containing a given spatial preposition such as "The chicken is *on the right* of the cat". Note that converseness holds in (b) but not in (a).

direct consequence, the informativeness of the spatial description; consider also that processing these prepositions when the relative reference frame has been assigned would make this effect even more compelling. In this experiment we expected that the scenes where converseness does not hold the informativeness is compromised and therefore the given spatial descriptions should receive lower ratings. An example of a scene where the converseness does not hold is illustrated in Figure 5.2a: For this scene the chicken can be described as being *to the right of* the cat within both the relative and intrinsic frames. However, the cat is not to the left of the chicken within the intrinsic frame, so converseness does not hold. On the other hand ratings for the scene where converseness holds should not be altered according to the view that the probability of the number of states of the world where this description is true is lower than the case in which converseness does not hold.

5.2.2 Method

Participants

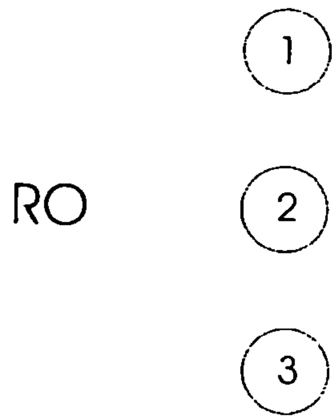

Figure 5.3: Here are illustrated the three locations where the LO could appear.

Twenty eight undergraduate students (1 male and 27 females) participated for course credit. All the participants were English native speakers, with normal or corrected to normal vision and none of them took part in any of the previous experiments.

Design and Materials

The experiment used an acceptability rating task where participants had to rate the acceptability of sentences containing the following spatial prepositions; *on/to the left on/to the right.* We used objects with a well defined intrinsic axis (OA object) and we used 4 orientations for both the RO and the LO; 2 on the vertical axis ("vertical" and "upside down") and 2 orientations on the horizontal axis ("facing towards" or "facing away" from the participant)

The LO could appear in 3 possible locations (see Figure 5.3); aligned with the RO (location 2), above the RO (location 1) or below (location 3) the RO; locations 1 and 3 were randomised within subjects and collapsed for the data analysis. The location on the screen of the RO-LO pair was randomised so that participants did not see the objects always in the same location. Summarising, the experiment included the following factors; 2 vertical orientations X 2 horizontal orientations X 2 spatial prepositions (*on the left/right* and *to the left/right*) X 2 horizontal locations for the LO (left vs. right) X 2 vertical locations for the LO (locations 1 and 3 collapsed vs. aligned, that is location 2) X 2 sentence values (true vs. false) X 8 OA objects (balanced for the LO only) for a total of 512 trials. The experiment used a within-subjects design. All the pictures were the same size in order to control "center-of-mass" and "proximity" effects (Regier & Carlson, 2001). The pictures were black and white and the level of brightness was the same for every picture. The stimuli were presented using the experiment generator E-prime™.

Procedure

The procedure was the same as that used in earlier experiments, except the following spatial prepositions were included: (*on/to the left/right*).

5.2.3 Results

The analysis focused on true trials, that is scenes where the sentence matched the location of the LO with respect to the RO both within the relative and the intrinsic reference frames. Given that the principal aim of this experiment was to determinate whether converseness affects the apprehension of *on/to the left* and *on/to the right* spatial prepositions, we coded which trials presented and which did not present a violation to converseness (examples of these have been extensively explained above in the introduction for this experiment).

In this analysis the variables included in the design were the following: 2 converseness values (holds vs. does not hold), 2 locations for the LO (right vs.

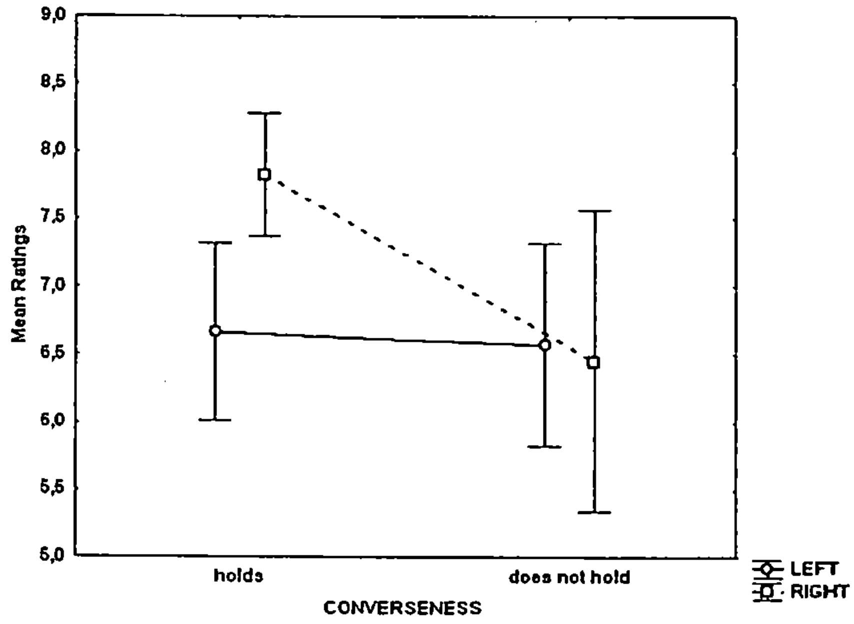

Figure 5.4: The 2-way interaction between converseness and location of the LO.

left), and 2 spatial prepositions (*on* vs. *to*). Table of means and SDs can be found in table 14 in appendix C. The analysis found a main effect of the location of the LO ($F(1,27) = 23.22$, $MSE = 15.04$, $p < .00001$) with the scenes with the LO on the right side judged as more acceptable ($M = 7.13$) than scenes with the LO on the left ($M = 6.6$). We also found a main effect of converseness ($F(1,27) = 14.74$, $MSE = 30.27$; $p < .0001$) with the sentences describing scenes where it does not hold being judged less acceptable ($M = 6.5$) than the descriptions for scenes where converseness holds ($M = 7.24$). Finally we found a 2-way interaction between converseness and location of the LO ($F(1,27) = 10.94$, $MSE = 23.06$; $p < .01$); these results are illustrated in Figure 5.4. The post-hoc test revealed that ratings were affected by converseness only when the LO was located on the right ($M = 7.82$ vs. $M = 6.45$; $p < .0001$). No other comparisons reached the significance.

5.2.4 Discussion

This experiment investigated the role of converseness on the comprehension of the spatial prepositions *on/to the left on/to the right.* The results suggested that converseness affects the acceptability of these projective spatial prepositions. However, curiously the effect was only found when the LO was located on the right. In addition we compared the effect of converseness for the spatial prepositions *on* vs. *to*. As the analysis revealed, there was no difference in terms of rating between these prepositions suggesting that these spatial terms can prompt equally intrinsic and relative frames. The results also suggest that converseness affects acceptability ratings also when the objects are shown in a canonical view. This discounts the alternative explanation that participants' judgments may simply reflect the degree of plausibility or "usualness" of a scene.

In summary we have shown that converseness affects the apprehension of spatial terms *on/to the left* and *on/to the right* . However, the effect was significant only for the scenes where the LO was presented on the right of the RO. In the next experiment, we investigate whether the effect of converseness can also be found in situations where participants are forced to prefer an intrinsic reference frame by using objects represented in plan view ("bird's eye" view).

5.3 Experiment 7

With the previous experiment we have extended the converseness hypothesis to a new set of spatial prepositions, *on/to the left* and *on/to the right*, showing that the orientations of located objects play a central role in the apprehension of spatial descriptions. However, the objects used had their orientation axis parallel to the gravitational plane. In this experiment we used objects represented from a different perspective (plan view) in order to investigate whether the converseness effect has anything to do with the process required to assign the sides of the objects. In fact identifying the intrinsic sides of objects when objects are rotated in two planes may be very challenging, although this hasn't been tested directly in the literature. For this reason we examined the same spatial prepositions *on/to the right of* and *on/to the left of* showing participants scenes involving people represented from a vertical perspective, in plan view. The paradigm was the same as the previous ones, where people were asked to judge the appropriateness of a sentence containing a spatial preposition to describe a scene.

5.3.1 Method

Participants

Twenty nine people (7 male and 22 female; age range from 20 to 30, mean age = 24) participated in this experiment on a voluntary basis. All the participants were Italian native speakers [1] with normal or corrected to normal vision. None of them participated in any of the previous experiments.

Design and Materials

Participants read the instructions on the computer screen including two example trials which illustrated the difference between a relative reference and an intrinsic reference frame. This was done to explain that both the descriptions

[1]The only reason because we used speakers of a different language was that the researcher was in Italy at the time . No cross-linguistic differences were expected as the structure in Italian for these terms is identical to English.

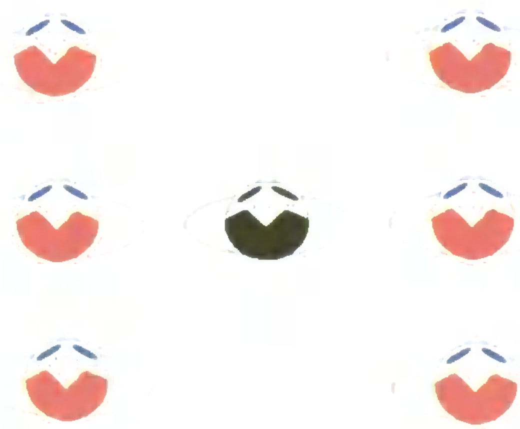

Figure 5.5: Here are illustrated the six possible locations where the LO could appear. In the analysis we coded the locations of the LO with respect to the RO as "aligned" (on the same plane as the RO) or "misaligned".

were compatible with the scene and that the participants were free to choose the preferred one. The paradigm was an acceptability rating task where people had to judge the appropriateness of a spatial description to describe given spatial scenes. The stimuli were pictures of two people represented in a plan view; Mr Red (in Italian *Sig. Rossi*) and Mr Black (in Italian *Sig. Neri*). The name coincided with the hair colour of the two men. Mr Black was always the reference object whereas Mr Red was always the located object. The LO could appear in six different locations respect to the RO (in order to show the LO in both *good* and *acceptable* areas) (see Figure 5.5). Both the men could appear in the following orientations; 0°, 90°, 180° or 270° degree. All the images were 150 x 150 pixels wide, had a 24 bit colour definition and were edited by Photoshop™.

Procedure

After participants had read and understood the instructions, the screen showed a sentence (e.g. "Mr Black is *on the left* of Mr Red") followed by a scene that represented the two men. The scene remained on the screen until participants pressed the button to return their acceptability judgment. The experiment was programmed and run using E-Prime™. The total number of trials was 256 based on the design that included the following variables: 2 spatial prepositions (*on the left/right* and *to the left/right*), 2 sides (left and right), 2 horizontal locations for the LO, 2 vertical locations for the LO, 4 orientations for the LO and 4 orientations for the RO. The design was fully balanced within subjects.

5.3.2 Results

The analysis focused on trials critical for converseness as in the previous experiment, coding the scenes where the orientation of the two men does or does not allow participants to apply converseness. As in the previous experiments we expected to find lower ratings for trials where converseness did not hold compared to scenes where the converseness did hold. For example the scene illustrated in figure 5.6, shows a configuration where converseness does not hold; in fact the scene can be described as "Mr Red is *on the right* of Mr Black" but also as "Mr Black is *on the right* of Mr Red" leading to a failure of the converseness inference.

The ANOVA included, among other factors, spatial prepositions *on* vs. *to*. However, given that, as in Experiment 6, an early analysis did not reveal any effect for these spatial prepositions we dropped this factor in order to simplify the analysis. Thus the variables included were 2 sides (left and right), 2 horizontal locations for the LO, 2 vertical locations for the LO (aligned vs. not aligned), and 2 converseness values. This analysis compared descriptions for those scenes where

Figure 5.6: This picture illustrates the case where converseness does not hold because from the intrinsic reference frame the men are both *on the right of* each other.

converseness clearly did not hold (see Figure 5.6) with those where converseness did hold. Table of means and SDs for this analysis can be found in table 15 in appendix C.

The analysis revealed a main effect of converseness ($F(1,28) = 8.76$, $MSE = 3.19$, $p < .01$), with higher ratings for the sentences describing the scenes where converseness holds ($M = 4.46$) than for scenes where converseness does not hold ($M = 4.29$). We also found a main effect of alignment ($F(1,28) = 6.73$, $MSE = 15.72$, $p = < .05$) showing an overall preference for descriptions where the LO and the RO are not aligned ($M = 4.56$) compared to the descriptions for the scene where the men are aligned ($M = 4.2$). No other main effects were found.

The analysis revealed a significant 2-way interaction between side and location of the LO ($F(1,28) = 55.22$, $MSE = 640.1$, $p < .0001$) that reflects the concordance among location of the LO and the side where it was shown in relation to the RO. The second significant 2-way interaction concerns the side of the LO and converseness ($F(1,28) = 31.5$, $MSE = 10.41$, $p < .0001$). For the scenes where the LO was on the left side, post-hoc analysis revealed that when converseness

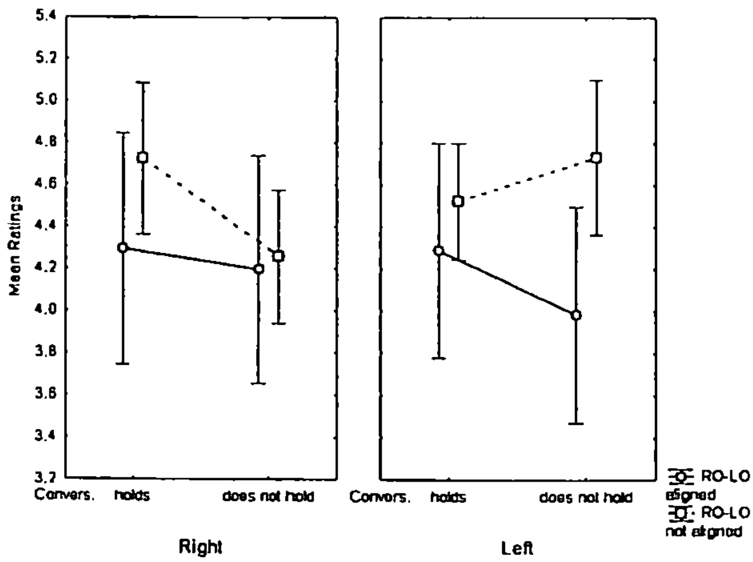

Figure 5.7: This picture illustrates the 3-way interaction between side, alignment and converseness.

was not violated, acceptability ratings were higher (M = 4.66) compared to scenes where converseness did not hold (M = 4.2). Sentences describing the scenes where the LO was shown on the right of the RO, when converseness holds acceptability ratings were higher (M = 4.25) compared to the description for scenes where converseness did not hold (M = 4.38).

The ANOVA also revealed a 3-way interaction between side, alignment and converseness (F(1,28) = 11.43, MSE = 5.67, p = .002), and the results are illustrated in Figure 5.7. The post-hoc analysis revealed that sentences for scenes where the LO was on the right of and misaligned to the RO ratings were higher when converseness held (M = 4.72) than for scenes where converseness did not hold (M = 4.25). Similarly, spatial descriptions for scenes with the LO on the left of and aligned to the RO showed higher ratings (M = 4.28) than scenes where converseness did not hold (M = 3.98). The analysis did not reveal any converseness effects within the other conditions.

Finally we found a 4-way interaction between side, location of the LO, alignment and converseness ($F(1,28) = 4.53$, $MSE = 1.43$, $p < .05$). Focusing on the trials where the spatial preposition and the location of the LO respect to the RO were congruent, we found a converseness effect for the all levels of alignment but not for all the location of the LO. In fact sentences for scenes with the LO on the left side of and aligned to the RO showed higher ratings when converseness hold (M = 5.69) than when it does not hold (M = 5.13). For descriptions where scenes with the LO on the right side of RO converseness effect were found only when the LO and the RO were not aligned (converseness holds M = 5.47; converseness does not hold M = 5.44). These results indicate that converseness affects the spatial apprehension process but only under some conditions.

5.3.3 Discussion

This experiment found evidence that for scenes where the logic of converseness does apply, the acceptability for the spatial description containing the spatial prepositions *on/to the left* and *on/to the right* decreased significantly suggesting that this mechanism is not spatial preposition specific, but is important for a wide range of spatial relations. However, the effects of converseness found in this experiment were limited to some conditions. A possible explanation is that, as for Experiment 6, people used a combination of an intrinsic reference frame and a relative reference frame; a consequence of this it that the applicability of converseness is less restricted, and therefore its effect weaker.

In the next experiment, the last one involving projective prepositions, we investigated the effect of converseness effect with the spatial prepositions *in front* *of* and *behind*. These projective prepositions have the properties to allow only intrinsic frame use; in fact in judging the appropriateness of a spatial term such as *in front of* the direction where the objects are facing is the only aspect that has to be considered (Harris & Strommen, 1972; Landau, 1996; Levelt, 1984; Levinson, 1996b).

5.4 Experiment 8

5.4.1 Introduction

We have shown thus far that, in relation to scene descriptions, the concept of converseness affects people's acceptability judgements for superior and inferior prepositions using both mono and poly-oriented objects. Earlier experiments have been careful to eliminate alignment of LO and RO axes and identification costs at increased rotation as potential alternative explanations of the effect. However, as mentioned earlier in this chapter, conditions involving flouting of converseness for vertical prepositions always involved the objects presented in orientations that could perhaps be regarded as "less usual" than scenes where converseness did hold. So although a carrot is as easy to identify individually when canonically oriented or at other rotations, the whole scene involving a carrot at a less usual orientation may still possibly account for changes in acceptability ratings. For that reason, and to afford generalisation to other spatial relations, we ran a new experiment with two new spatial relations; *in front of* and *behind*. Previously, functional effects for spatial prepositions such as *over/under* and *above/below* have also been found for *in front of/behind* (Carlson-Radvansky & Radvansky, 1996). These spatial terms have been investigated by Landau (1996) who showed that children of all the ages generalised their interpretation of *in front of* to

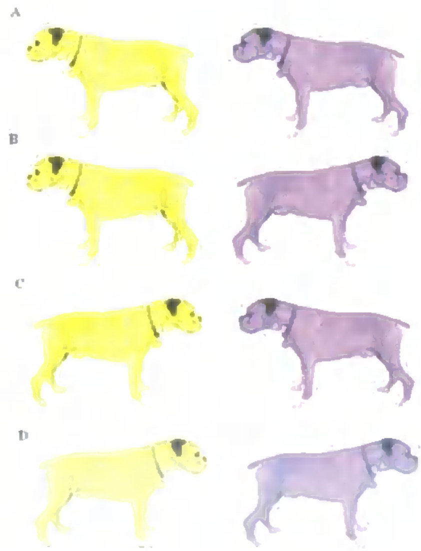

Figure 5.8: Examples of scenes used in Experiment 8.

regions with a well-defined geometry. That was based on extension outward of the object's principal axis placing an object *in front of* another object directly in line with the intrinsic front of the reference object. However, the potential influence of converseness for these terms has not been tested before, so it is interesting to see whether the effects found in previous experiments can be generalised.

Consider the scenes in Figure 5.8. In 5.8A , the purple dog is *behind* the yellow dog is true with respect to the intrinsic frames. And one can say that the yellow dog is *in front of* the purple dog. So converseness holds for this scene. Now consider 5.8B. Here the purple dog is *behind* the yellow dog is also true with respect to both the intrinsic and relative frames, but this time converseness does not; the yellow dog is *in front of* the purple dog is false. So if converseness is important more generally to the processing of visual scenes we would hypothesise that ratings for spatial expressions containing *in front of/behind* to describe scenes where converseness holds (e.g., Figures 5.8A and 5.8D) will be higher than for those scenes where converseness does not hold (e.g., Figures 5.8B and 5.8C). Note that the orientations of the LO for the case where converseness does or does not hold are aligned in the vertical plane. So there are no grounds for arguing that a scene where converseness holds is somehow more unusual than when converseness does not hold.

5.4.2 Method

Participants

Twenty students (14 females and 6 males; age range from 18 to 44, mean age = 22) participated in this study for credit course. All participants were English native speakers with normal or corrected to normal vision that had not taken part in the previous experiments.

Design and Materials

This experiment employed an acceptability-rating task similar to the previous experiments, except in this case two new prepositions were used; *in front of* and *behind*. A new set of eight objects was selected such that each object had a clear front/back orientation when presented in profile (e.g., man, penguin, rhinoceros). The full list of objects employed in this experiment can be found in Appendix D. Each scene consisted of a pair of objects (e.g., two men, two penguins etc.), with the RO and LO being distinguished by different colours (see Figure 5.8 for examples). The scenes were described by sentences of the form <<The LO is *spatial preposition* the RO>> (e.g., "The red man is *behind* the yellow man"; "The green penguin is *in front of* the purple penguin"). All the images were 150 x 150 pixel wide, had a 24 bit colour definition and were edited by Photoshop^{TM}. Each object could be placed either facing to the left or to the right, with the LO being positioned to the left or right of the RO. The objects were placed either 300 pixels (that correspond to 8,93 cm on a 17" monitor; near distance) or 400 pixels (that correspond to 11,97 cm; far distance) apart. The objects were only manipulated along the horizontal axis and were not rotated in any scenes. In other words, orientation of objects was only to the left or to the right. As with the previous experiments, the placement of the object pairs was randomised to different screen positions to prevent participants from seeing objects in predictable locations.

The design included the following factors; 2 (spatial prepositions: *in front of, behind*) x 2 (distance of LO to RO: far or near locations) x 2 (side: LO placed on the left-hand side or right-hand side), x 2 (direction of LO: facing left or facing right) x 2 (direction of RO: facing left or facing right), x 8 (LO objects), x 2 (object colour: two colours for each object pair), resulting in a total of 512 stimuli. Because of the large number of trials it was decided to split the material set in two using the object colour factor as a between participant factor, giving a total of 256 trials for each participant. As for the other experiments in this chapter, half of all trials were true and half were false.

Procedure

The procedure was the same as that in Experiments 1-2-3.

5.4.3 Results

The mean acceptability ratings for true instances of *in front of* and *behind* by distance and converseness (present or absent) are displayed in Table 6. The data were analysed using a 2 prepositions (*in front of* vs. *behind*) x 2 distances (near vs. far) x 2 converseness (present vs. absent) within participants ANOVA.

Table 6
Mean acceptability ratings (and SDs) for the spatial prepositions as function of the distance and converseness

Converseness		IN FRONT OF	BEHIND
Holds	Near	8.09 (1.58)	8.05 (1.56)
	Far	8.06 (1.57)	7.9 (1.6)
Does not hold	Near	6.62 (1.94)	6.03 (2.2)
	Far	6.78 (1.91)	6.05 (2.25)

The results revealed a main effect of preposition ($F(1,19) = 7.96$, $MSE = 0.71$, $p < 0.01$). Overall ratings for *in front of* were significantly higher ($M = 7.39$) than those for *behind* ($M = 7.02$). There was also a main effect of converseness ($F(1,19) = 8.07$, $MSE = 13.75$, $p < 0.01$). When the objects were facing toward to the same direction (that is the condition where converseness holds) ratings were significantly higher ($M = 8.04$) than when the objects were facing opposite directions (here converseness was not present) ($M = 6.36$). There was no effect of distance, nor any interactions between any of the variables. The complete ANOVA table can be found in Table 16 in appendix C.

5.4.4 Discussion

The aim of this Experiment was to establish whether our previous findings could be generalised to other spatial relations; the results support this hypothesis.

Moreover, the presence of a converseness effect for *in front of/behind* eliminates any doubt that the LO orientation effect found for vertical relations has to do rather with the degree of unusualness of the scene being described.

5.5 Summary

In earlier chapter we have shown that spatial descriptions containing spatial prepositions such as *above, below, over* and *under* were rated significantly lower when converseness did not hold. In this chapter we have shown that the converseness principle is a valid explanation also for spatial prepositions such as *on/to the left/right* and *in front of* and *behind* which are prepositions that refer to the horizontal plane. However the effect of converseness was much stronger and solid for the spatial prepositions *in front of/behind* compared to the *on the left/right.* This may be because the latter allows people to use a relative and an intrinsic reference frame while the former only allows intrinsic frames use. Therefore the violation of converseness has a strong impact on the spatial terms *on the left/right* because in case of conflict there are no alternative descriptions available. On the other hand, when converseness failed with the intrinsic interpretation of *on the left/right* the interpretation based on the relative reference frame is still available. In the next chapter we consider instead the role of informativeness for the comprehension of proximity terms *near* and *far*.

Chapter 6

Proximity Prepositions: *Near & Far*

6.1 Introduction

In the earlier chapters, across 8 experiments, it has been shown that the degree to which converseness holds affects the extent to which a given spatial expression (containing a projective spatial preposition) is appropriate to describe a given spatial relation. The goal of this chapter is to test whether informativeness more generally may affect the comprehension of other spatial prepositions where converseness simply does not apply. This is the case for proximity spatial terms such as *near* and *far* that are immune to the principle of converseness: The inference "B is *far* from A" does not follow from "A is *near* B". Although converseness does not apply for these proximity terms, informativeness can be tested with respect to the presence of other NEAR/FAR relations in the visual scene being described.

We have already seen that the informativeness of a spatial proposition can be seen as the inverse function of the number of states of the world that the proposition rules out (Bar-Hillel, 1964): Accordingly, an utterance is more informative when it describes to a unique spatial array than when it refers to multiple spatial relations. For example with proximity spatial prepositions the description "A is *near* B" will be more informative when the description refers to a scene where a NEAR relation is the only relation available to describe the spatial relation between the objects.

One of the principle means used to establish uniqueness is context. Indeed there is emerging evidence that context can affect the interpretation of spatial expressions. For example the spatial term *near* in "the ball is *near* the hole" elicits a different meaning when the description refers to a golf course as compared with a snooker table (Coventry & Garrod, 2004; Miller & Johnson-Laird, 1976). In the same vein Carlson and Covey (2005) showed that the perception of distances is in relation to the size of the objects being described: Estimates were smaller for smaller objects and larger for larger objects. Further studies have shown that the context leads to a change in scale in relation to functional interaction between the objects being described. Thus two pairs of objects, placed at the same distance, were judged as more *near* when the position of the two objects allowed functional interactions than a pair of object that could not functionally interact (Coventry, Mather & Crowther, 2003; Ferenz, 2000). McNamara (1986) investigated the mental representation of spatial relations asking participants to learn the location of objects in spatial layouts or the location of objects on maps of those layouts. The results showed that all the tasks (item recognition, direct judgments and Euclidean distance estimation) were sensitive to whether objects were in the same region or in different regions and that the euclidian distances between pairs of objects affected the performance. In addition Carlson and van Deman (2004) used a response time paradigm to demonstrate that distance is encoded during the processing of projective spatial terms contrary to claims made by Logan and Sadler (1996).

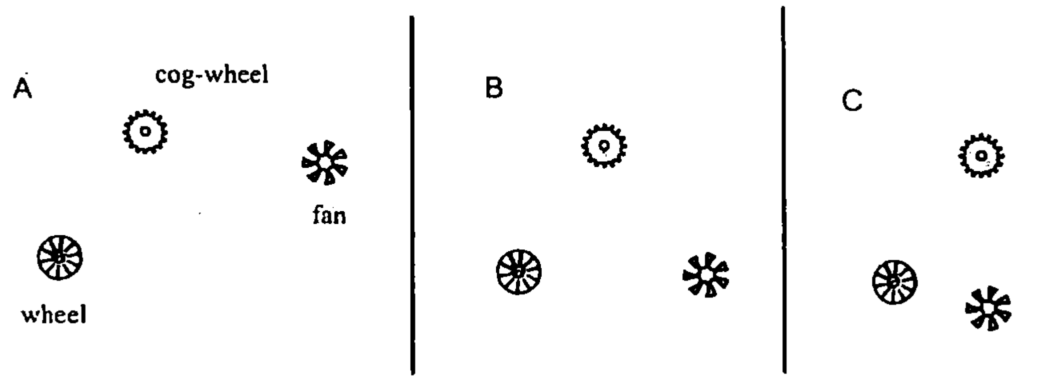

Figure 6.1: "The wheel is *near* the cogwheel". In A the NEAR relation is unique for the mentioned object. In B *near* suits the distance of both the location of the LO and the location of the irrelevant object (the fan) in relation to the wheel. In C, the relationship between the fan and the wheel offers a more suitable example of a NEAR relation.

These examples show that non-spatial semantics of an object may govern prepositional usage and that the context in which the objects are presented plays an important role in the apprehension of proximity spatial prepositions. In the experiments reported in this chapter we investigate whether manipulating the context in which the objects are presented will affect the informativeness of the proximity spatial prepositions *near* and *far*. In this case the context is manipulated by showing a third object (together with the LO and the RO) in the scene in order to test whether people will consider the new irrelevant object when processing the distance between the LO and the RO. For example the three spatial arrays in figure 6.1 can be described with the same sentence; "the wheel is *near* the cogwheel". In "a" the irrelevant object (the fan) occupies a position (FAR) that is not conflicting with the relation defined in the sentence (NEAR) and may make, by contrast, the spatial preposition ***near*** more appropriate to describe the location of the LO with respect to the RO. In "b" the location of the irrelevant objects in relation to the LO occupies the same relation as that between the LO and the RO making the given spatial description less informative because the relation NEAR can be used to describe the location of both the objects. In "c" the location of the irrelevant object offers an even more suitable example for the proximity preposition and this should make, by contrast, the spatial prepositions *near* less appropriate to describe the location of the LO with respect to the RO. In the next experiment we manipulated the distance between the irrelevant object and the LO whereas LO-RO distances and the distances between the RO and the irrelevant object were always identical. This was important given that distance between a third object (the irrelevant objects) and the LO would clearly offer a comparison distance to consider.

6.2 Experiment 9

6.2.1 Method

Participants

Thirty participants (25 females and 5 males; age range from 20 to 42, mean age = 24) participated on a voluntary base in this study. All participants were Italian native speakers [1]and had normal, or corrected to normal, vision. None of them was aware of the hypotheses of the research.

[1]Again the only reason why we used speakers of a different language was that by the time I collected these data, I was in Italy. Italian and English have the same set of proximity terms in their spatial lexicons.

Design and Materials

An acceptability rating task was used to measure the appropriateness of the spatial prepositions *vicino* (*near*) and *lontano* (*far*) in describing a spatial scene. Such scene showed three objects; a Reference Object (RO), a Located Object (LO) and an irrelevant object not mentioned in the sentence to be rated (I). Two distances were used between the RO and LO; 200 pixels (this distance is here and after named X) or 400 pixels (this distance is here and after named 2X). Distances between the RO and the I were the same as the distances between the LO and RO. Distances between the LO and I were calculated in relation to the distances between the RO and the LO, in order to keep the proportions between distances always constant. The formula used to calculate the relative distances can be found in appendix E. The possible LO-I distances were: $\frac{2}{3}$X, X and $\frac{4}{3}$X where X was the distance between the LO and the RO (200 or 400 pixels). The selection for these fractions was imposed by the limited size of the monitor (larger fractions did not fit within the screen bounds).

We also introduced three procedures that showed the pair of objects in different orders. This manipulation has been included for two reasons: First to exclude the possibility that people could predict which objects will be shown thus, avoiding the need to process the irrelevant object and its relative location. Second to explore whether showing the pair with the irrelevant objects first, would prime that spatial relation that, in turn, could be used as anchor for the final judgment. The objects could appear in the following orders: Order 1 showed the LO-I pair first, followed by the RO; Order 2 showed the LO-RO pair first, followed by the I and Order 3 showed the RO-I first, followed by the LO.

Object locations were randomised thus participants did not see the triad of objects always at the same location (6 series of coordinates were randomly allocated to the *near/far* trials). All the objects were of the same size (150 x 150 pixels) to control "centre-of-mass" and "proximity" factors, which have been shown to affect the appropriateness of spatial prepositions (Regier & Carlson, 2001). Pictures were white on a black background and the level of brightness was the same for all of them. The objects were circular shaped objects in order to keep the distance among them strictly controlled. The set of stimuli comprised eight objects; a shield, an ashtray, a wheel, a cog, a port hole, a circle, a fan and a football. In summary, the experiment included the following variables; 8 circular shaped objects (random factor), 2 RO-LO distances, 3 LO-Irrelevant distances, 2 spatial prepositions, 3 presentation orders for a total of 288 trials. All the variables were tested within-subjects and the stimuli were presented using the experiment generator E-prime ™.

Procedure

Given that the objects used were all of similar size and shape, it was important to assure they could be adequately differentiated from one other. Therefore during the briefing, participants were shown a hard-copy of each object used in the experiment in order to eliminate recognition problems. Trials started with a sentence in the following format <<the LO is *spatial preposition* the RO>> that remained on the screen until the participant pressed the space bar. Afterward a blank screen (300ms) appeared, followed by the first pair of objects presented for 1500ms before the third object appeared. Once all the objects were on the screen the participant had to press a button for the judgment. An inter-stimulus interval (ISI) of 600ms ended the trial. The experiment also included a number of irrelevant questions (e.g., "Was the word SHIELD mentioned in the last sentence?") about the objects mentioned in the sentence in order to force participants to read

Table 7
Mean acceptability ratings (and SDs) for spatial prepositions *near-far* as a function of the LO-I distance, LO-RO distance; and presentation order.

LO-I distance X LO-RO distance		Spatial Preposition FAR			NEAR		
		Pres.1	Pres.2	Pres.3	Pres.1	Pres.2	Pres.3
SHORT	LO-RO short	2.5(0.16)	2.4(0.14)	2.6(0.16)	6.8(0.17)	7.4(0.14)	7(0.16)
	LO-RO long	7(0.2)	6.9(0.21)	7.1(0.19)	2.9(0.23)	3(0.25)	3(0.23)
SAME	LO-RO short	2.2(0.16)	2.1(0.14)	2.3(0.13)	7.5(1.6)	7.6(0.17)	7.3(0.19)
	LO-RO long	6.8(0.2)	6.6(0.23)	6.8(0.22)	3(0.22)	2.9(0.24)	2.8(0.22)
LONG	LO-RO short	2.2(0.16)	2.2(0.12)	2.3(0.15)	7.1(0.18)	7.4(0.18)	7.4(0.18)
	LO-RO long	6.9(0.2)	6.8(0.22)	7.2(0.2)	3.1(0.22)	3.2(0.22)	2.9(0.21)

the sentences, and to look at all the objects independently if they were mentioned in the sentence or not.

6.2.2 Results

Acceptability ratings were submitted to a 2 spatial prepositions (*near/far*) X 2 RO-LO distances (X vs. 2X) X 3 LO-I distances ($\frac{2}{3}$X, X, and $\frac{4}{3}$X) X 3 presentation orders (LO-I first, LO-RO first, and RO-I first) mixed ANOVA. The whole results are reported in table 17 in appendix C while Table 7 displays the means and standard deviations. A significance level of $p < .05$ was adopted unless otherwise specified, and where follow-up analyses are reported, LSD tests were used.

To start with, data analysis revealed a significant interaction between RO-LO distance and spatial prepositions ($F(1,29) = 127.88$, $MSE = 28.84$, $p < .00001$).

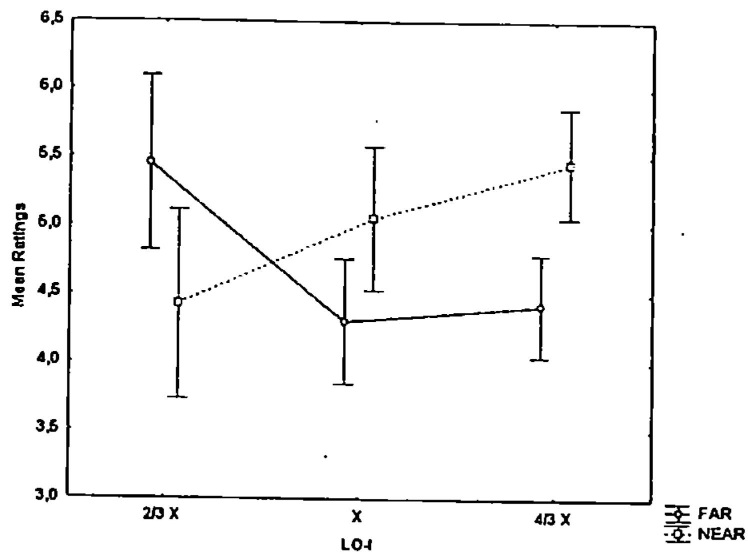

Figure 6.2: This figure illustrates the interaction between the LO-I distance and the spatial prepositions used in the descriptions.

This trivial result showed that bigger RO-LO distances were associated with the spatial term *far* and shorter RO-LO distances were associated with *near*. In particular *far* received higher ratings (M = 6.7) for the scene with the LO-RO at 400 pixel distance compared to the scene with the LO-RO distance set at 200 pixel (M = 3.15; $p < .0001$). *Near* received higher ratings (M = 6.63) within trials showing the LO-RO at 200 pixels distance than trials showing the objects at 400 pixel (M = 2.79; $p < .0001$).

Data analysis also revealed a significant interaction between LO-I distance and spatial preposition ($F(2,58) = 19.37$, MSE = 4.3, $p < .00001$) illustrated in Figure 6.2. This interaction showed that the acceptability for the spatial preposition *near* increased as function of the LO-I distance. In fact, trials with the LO-I distance set at $\frac{2}{3}$X received the lowest ratings (M = 4.49), while trials with the LO-I distance set at X (M = 5.15) and $\frac{4}{3}$X (M = 5.30) received respectively higher ratings. However, only the $\frac{2}{3}$X and the $\frac{4}{3}$X distances were significantly different ($p < .0001$). With *far* trials, we found the opposite trend: Lowest ratings were given to trials with the LO-I at X (M = 4.39) and $\frac{4}{3}$X distance (M = 4.45), while the highest acceptability was for trials with the LO-D distance set at $\frac{2}{3}$X (M = 5.49). The later condition was significantly different from both X and $\frac{4}{3}$X distances ($p < .00001$).

We also found a a significant 2-way interaction between presentation order and spatial prepositions ($F(2,58) = 6.75$, MSE = .31, $p < .005$). Follow up analysis revealed a significant difference between *far* trials where RO-LO were shown first (M = 4.56) compared to trials where the first pair of objects was LO-I. (M = 4.63; n.s.) or the RO-I pair (M = 4.7; $p > .05$). Scenes with the spatial term *near* received higher rating when the RO-LO pair appeared first (M = 5.18) compared to scene where the LO-I pair was shown first (M = 5.08; $p < .01$) or the RO-I pair was shown first (M = 4.98; $p < .0001$).

Of most interest, the analysis revealed a significant 3-way interaction concerning the LO-I distance, the RO-LO distance and spatial prepositions ($F(2,58) = 18.07$, MSE = .477, $p < .00001$). Trials where the RO-LO distance set at X was matched with spatial preposition *near*, the shorter LO-I distance (M = 6.02) received the lowest acceptability ratings. This was significantly different from scenes with the longest LO-I distance set at $\frac{4}{3}$X (M = 7.1; $p < .00001$) and the LO-I distance set to X (M = 7; $p < .00001$). Trials where the RO-LO distance set to 2X was matched with the spatial preposition *far* showed a higher acceptability for the LO-I distance set at $\frac{2}{3}$X (M = 7.16). This was significantly different from scene showing the longest LO-I distance (M = 6.43, $p < .00001$) and scenes with the LO-I distance set to X (M = 6.33; $p < .00001$). Trials showing the RO-LO at

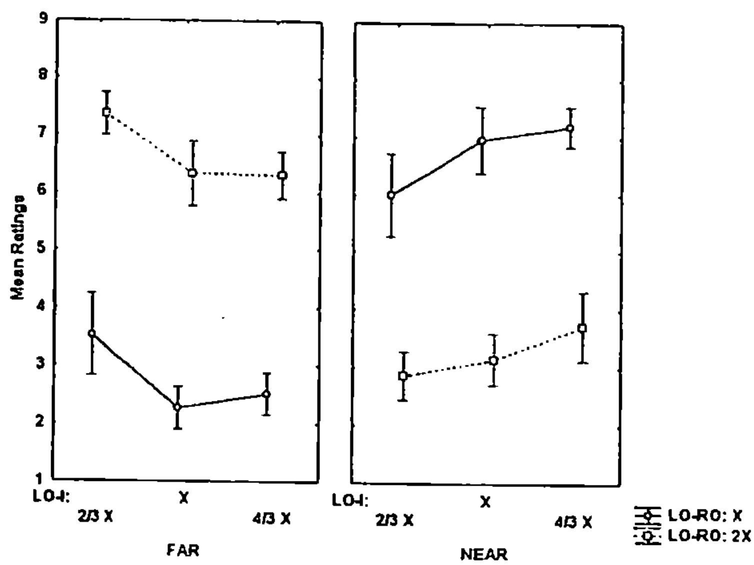

Figure 6.3: This figure illustrates the 3-way interaction between LO-I distance, RO-LO distance and spatial prepositions.

X distance matched with spatial preposition *far*, the lowest acceptability was for the LO-I located at the same RO-LO distance (M = 2.4) or bigger distance (M = 2.6). The most acceptable examples were those with the LO-I distance set to $\frac{2}{3}$X (M = 3.56; $p < .00001$ for both the comparisons). Trials showing the RO-LO at 200 pixel distance matched with spatial term *near* showed higher ratings for the longest LO-I distance (M = 3.49). Follow-up analysis revealed that this rating was significantly different from scenes with LO-I distance set at X (M = 3.06; $p < .00001$) and the LO-I distance set to $\frac{2}{3}$X (M = 2.91; $p < .00001$).

The data analysis also revealed a 4-way interaction between LO-I distance, RO-LO distance, spatial prepositions and presentation order ($F(4,116) = 4.49$, $MSE = .182$, $p < .005$). Given that this was the case, we ran three separate analyses; one for each presentation order. For all three presentation orders critically the three-way interaction between LO-I distance, RO-LO distance and spatial prepositions was reliable, and in the same direction as reported above. However, the magnitude of the interaction was greatest when the LO-I distance was presented first.

6.2.3 Discussion

The results of this experiment indicate that the distance not involving the LO-RO pair is taken into account when determining the appropriateness of *near* and *far* to describe the distance between the LO and the RO. In other words *near* is more appropriate if it specifies a LO-RO relation when there is no other NEAR relation in the scene being described. Vice versa, the results indicate that *far* is more appropriate when there are no other FAR relations in the scene being described. So, as in the earlier experiments, participants consider a relation not mentioned in the sentence to inform their judgments and this relation affects significantly the informativeness of the spatial description under examination.

Examples of the fact that participants take into account the spatial relations involving the irrelevant objects have been found for all the presentation orders suggesting that presenting the objects at different moments in time could have primed a specific distance. Experiment 10 therefore presented all three objects at the same time in order to establish whether the effect is due to contrasts of distance as a function of presentation order or not.

6.3 Experiment 10

The previous experiments showed that people, when determining the appropriateness of proximity spatial prepositions, take into account the distance not involving the LO-RO pair. This indicates that people do consider context when processing spatial prepositions. In addition, the previous experiment showed also that the degree with which the extra relation affects the acceptability of a spatial term is in relation to the presentation order of the objects. However, this effect has been found when the three objects were not displayed simultaneously. In order to discount the hypothesis that showing the objects in different orders could have primed a distance in the next experiment we attempted to replicate Experiment 9 but presenting the three objects (RO, LO and Irrelevant) at the same time.

6.3.1 Method

Participants

Twenty eight undergraduate (1 male and 27 female) participated for course credit. All the participants were Italian native speakers, with normal or corrected to normal vision.

Design and Materials

The experiment used an acceptability rating task where participant had to rate the acceptability of sentences containing the prepositions *near* and *far*. The design was similar to Experiment 9 with the difference that the three objects (LO, RO and I) were showed on the screen simultaneously. All the other variables were the same. The experiment included the following variables; 8 NA objects (the same NA objects used in the previous experiments) X 2 RO-LO distances X 3 LO-I distances X 2 spatial prepositions, for a total of 96 trials. The experiment used a within-subject design. As for the previous experiment the two distances between the RO and LO were; 200 pixels (X) or 400 (2X) pixels. The possible LO-I distances were: $\frac{2}{3}$X, X and $\frac{4}{3}$X where X is the LO-RO distance. All the pictures were transformed in the same size in order to control "center-of-mass" and "proximity" factors which have been show to affect the appropriateness of spatial prepositions in past studies (Regier & Carlson, 2001). The pictures were black and white and the level of brightness was the same for every picture. The stimuli were presented using the experiment generator E-prime ™.

Procedure

Participants had to judge the appropriateness of a spatial preposition (*near* and *far*) to describe scenes in an acceptability rating task picture. A sentence was shown before the scene and with the following form; <<the LO is *spatial preposition* the RO>>. After the sentence, a picture appeared showing the three objects. When ready, participants gave their judgment by pressing a number between 1 and 9 (where 1 = not at all acceptable and 9 = perfectly acceptable).

6.3.2 Results

The variables included in the analysis were the distance between RO and LO (X vs. 2X), the distances between LO and the Distractor ($\frac{2}{3}$X, X and $\frac{4}{3}$X) and finally two spatial prepositions; *near* and *far*. Table 8 reports a summary of results of the ANOVA where table of means and SDs (Table 18) can be found in appendix C.

The statistic found a main effect for prepositions ($F(1,27) = 52.36$, MSE =1.73, $p < .00001$) with higher ratings for *near* (M = 5.39) than *far* (M = 4.35) suggesting that, overall, participants found all the scenes more appropriately described by a NEAR relation. We also found a main effect of distance between RO and LO ($F(1,27) = 6.03$, MSE = .33, $p < .05$) with longer distances judged as more appropriate (M = 4.95) than short distances (M = 4.79). No other main

Table 8.
Mean acceptability ratings (and SDs) for near and far as function of the distances among the objects and the order of presentation.

LO-I distance X LO-RO distance		FAR	NEAR
SHORT	LO-RO short	3.1 (0.24)	6.23 (0.22)
	LO-RO long	5.5 (0.13)	4.23 (0.18)
SAME	LO-RO short	3.2 (0.21)	6.6 (0.18)
	LO-RO long	5.5 (0.12)	4.5 (0.15)
LONG	LO-RO short	3.2 (0.2)	6.5 (0.15)
	LO-RO long	5.6 (0.13)	4.3 (0.22)

effects were found. In addition we found a 2-way interaction between spatial prepositions and RO-LO distance ($F(1,27) = 86.2$, $MSE = 4.88$, $p < .00001$) (illustrated in Figure 6.4). Follow up analysis showed how the preposition *near* was more appropriate in describing short RO-LO distances ($M = 6.43$) than long RO-LO distances ($M = 5.35$) ($p < .0001$). *Far* was more appropriate in describing long RO-LO distances ($M = 5.54$) than short RO-LO distances ($M = 3.15$) ($p < .0001$). In addition, *near* and *far* were significantly different when compared for the short RO-LO distance ($p < .00001$). No other comparison was found significant.

6.3.3 Discussion

This experiment aimed to explore whether the effect of context depends on the order in which the objects are presented. The lack of interactions between the LO-I distance and RO-LO distance suggests that showing the objects in different orders is necessary to get the effect. This pattern of results suggests that

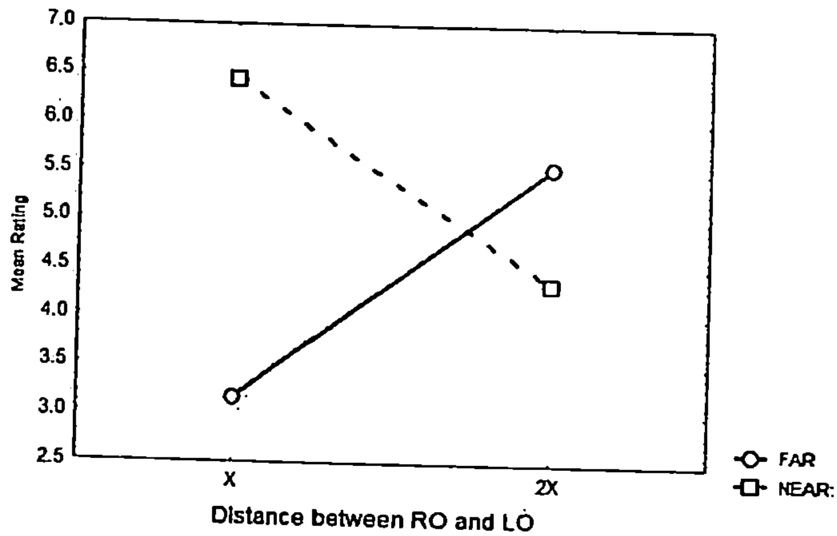

Figure 6.4: The 2-way interaction between RO-LO distance and spatial preposition.

people may use the LO-I distance as an anchor to set a scale for the judgment. The perception of nearness and farness depends on a scale set using available information that has been brought into attention. In order for a distance cue to be used contextually, that cue needs to be presented prior to the presentation of the relevant distance to be described or judged. The world consists of many possible distance cues, and automatic consideration of all possible cues would be cognitively demanding and would not serve the purpose of communication very effectively. It makes sense to only consider distance relations that are relevant for spatial description that is those that are in linguistic and/or attentional focus temporally adjacent to the spatial communication consistently with pragmatic rules (Grice, 1989).

6.4 Summary

In summary Experiment 9 and Experiment 10 investigated whether the principle of informativeness may affect the comprehension of other spatial prepositions where converseness simply does not apply. The overall results indicate that priming distance affects proximity terms, but informativeness does not appear to be central for these terms. In fact the results showed that while relative distance between LO and RO and I and RO clearly matters (i.e., if I is nearer the RO than L, the spatial term *near* is simply not felicitous), other distances only become important under some circumstances such as presenting the irrelevant objects first.

Chapter 7

General Discussion

Spatial language is one of the most common types of language, since people are often in situations where a spatial description is required; finding a street, finding your glasses, indicating a place, but also metaphorically talking about time, moods, and so on. Despite the ease with which people use spatial language, its apprehension requires a number of types of information that are not always related to the simple geometry. There is a growing body of evidence showing that people take into account conceptual knowledge about how objects are interacting or may interact when comprehending spatial language. For example, recently Carlson and Covey (2005) showed that distance processing inferred from a spatial description varies according to a whole host of contextual parameters. Further studies have shown that within extra-geometric factors we should include functional relations between the objects being described. In fact two pairs of objects, placed at the same distance, were judged as more *near* when the position of the two objects allowed functional interactions than a pair of objects that could not functionally interact (Coventry, Mather & Crowther, 2003; Ferenz, 2000). Despite the great interest in this aspect of spatial language, no study up to date had investigated whether communication principles as well as extra-geometric factors, must be taken into account in the spatial apprehension process. We believed that pragmatic principles of communication should be always satisfied: Therefore, showing a scene where the location of the objects is ambiguous because the same spatial relation can be used to describe the location of a different object within the same spatial array, should result in a failure of the Q-principle (Grice, 1975, 1989). As consequence, people should show lower acceptability for the given spatial prepositions that are informationally weaker in the context in which they occur.

The present thesis aimed to investigate whether the inferences people draw with regards to spatial relations, and in particular those based on the logic of converseness (Levelt, 1996), affect the extent to which spatial descriptions are regarded as acceptable to describe those spatial relations. Across four series of experiments, in a total of ten experiments, we investigated this issue across the following spatial prepositions: *above, below, over, under, near, far, in front of, behind, on the left, on the right.* In Experiments 1-5 we tested whether flouting of converseness through manipulation of the orientation of the LO affects the appropriateness of a spatial expression involving *over/under/above/below* to describe the position of an LO in relation to an RO. In particular, Experiments 1 and 2 established that the orientation of the LO does affect the appropriateness of a spatial expression containing vertical spatial prepositions to describe simple scenes containing two objects. Experiment 3 manipulated the orientations of both LO and RO in order to test the possibility that comprehension is affected by the extent to which the orientations of the LO and RO are aligned. It was possible that the orientation of the LO served merely to reduce confidence in the frame(s) that applied casting doubt on the orientation of the objects versus the whole scene. The results of this experiment showed that the effects of the orientation of the LO and orientation of RO are independent, and therefore this alternative explanation was not supported. The data from Experiments 4 and 5 also allowed us to discount a second alternative explanation for the effect - that the effect is associated with cost in identifying the LO. The effect of the orientation of LO persisted even when the LOs used were poly-oriented and therefore do not have increased cost associated with their identification as a function of increasing rotation away from canonical orientation. Moreover, even when judgements had to be made under time pressure (Experiment 5; a sentence-picture verification task), the orientation of LO effect persisted.

For converseness to be important, one would expect it to matter across a range of spatial relations, and not just for vertical spatial relations. Chapter 5 focused on a new set of prepositions, including *in front of, behind, on the left and to the right* with the aim of showing that converseness influences the acceptability of a wide set of spatial prepositions. Experiments 6, 7 and 8 provided evidence that converseness is relevant also for the apprehension of these prepositions. This was important not only for generalisability to other spatial relations, but also as the orientations of the LO for a test of converseness at least for *in front of/behind* exclude the possibility that the effect of converseness could be interpreted in terms of unusualness of a spatial scene. The results of these experiments indeed support a partial generalisability across spatial relations while dispelling alternative explanations for the effect.

Experiments 9 and Experiment 10 focused on the proximity spatial prepositions *near* and *far* showing that the informativeness of a spatial description can be affected by the context (represented by extra descriptions made available introducing an irrelevant object in the scene) although the principle that generates these descriptions was not converseness given that the logic cannot be applied to topological prepositions. In this regard it has been suggested that the findings from these experiments (but also from the previous experiments) can be explained by the alternative hypothesis that lower ratings reflect the fact that the given spatial array is consistent with multiple spatial descriptions (Handley, personal communication). However, this interpretation is compatible with the formal treatment of informativeness. In fact this theory basically states that a description is more informative as a function of the greater the number of states of the world a given preposition is able to exclude - that is how precisely a spatial array has been described. Thus the fact that a spatial array provides alternative descriptions makes automatically the given description less informative because there is more than one single state of the world that can be referring to.

Overall, the evidence collected in these experiments corroborates the hypothesis that speakers attempt to construct and test the most informative spatial model that can be established for the objects in a scene and such a model is the one which supports the strongest inferences about the situation that are consistent with the information present in the scene itself. Moreover we have shown that among the information speakers take into account in order to test the informativeness of the spatial description, speakers also apply the logic of converseness. The present results take spatial language from a process of establishing whether a given expression is true or not to a view of spatial language as affording inferences that people make about states of the world now and in the future.

While converseness is important for spatial language comprehension, it is also the case that the effects of the orientation of the LO were greater overall across the experiments for *above-over* than for *under-below*. This may be because overall superior relations were given higher ratings than inferior relations in most of the experiments, indicating that they are associated with a wider range of acceptable regions on the horizontal plane than *below-under*. So there are more positions where converseness comes into play for these terms than for *below-under*. Moreover, the effect of converseness was more apparent for some prepositions than for others across different axes. For example with *on the left* vs. *on the right* the results were clear only for the latter. On the other hand the spatial prepositions *in front of* and *behind* both exhibit a strong converseness effect. This can be explained in terms of reference frames: In fact *in front of-behind* prepositions, in the way we have shown in Experiment 8, accept only intrinsic frames, while *on the left* and *on the right* allow people to assign both an intrinsic or a relative reference frame. This does not reduce the impact of our findings but emphasises that converseness is easier to apply where a single (as for *in front of-behind*) or a particularly stronger (as for *above-below*) reference frame is available.

Informativeness has resulted to be important also for proximity terms that do not support the converseness principle showing that people take into account extra-linguistic information in spatial language apprehension. This effect however, can also be explained in terms of anchoring: People set a scale based on the best example of spatial relation and adjust the successive judgments in relation to that scale. The "Anchoring Effect" has received much interest in recent years, and it occupies a relevant role in social cognition (Jacowitz & Kahneman, 1995; Mussweiler & Strack, 1999; Strack & Mussweiler, 1997), decision making (Ritov, 1996; Rottenstreich & Tversky, 1997) and general psychology (Wilson, Houston, Etling & Brekke, 1996). The anchor effect is a biased estimate towards an arbitrary value considered by judges before making a numerical estimate (Jacowitz & Kahneman, 1995). Similarly two objects can be judged as *near* until another pair of objects shows a better NEAR relation (represented by the anchor).

The present results have implications for computational models of spatial language. Currently models of spatial language assume that direction is assigned from the RO to the LO after multiple reference frame activation, and that attention is directed from the LO to the RO in order to establish the goodness of fit between a given spatial preposition and a given visual scene (e.g., Regier & Carlson, 2001). The present research indicates that attention is distributed across both objects in the scene (Lavie, 1995, 1997) and that there is an active search for alternative spatial relations to describe those objects where attention must be allocated from the LO to the RO. Thus multiple reference frame activation is also likely to be triggered where reference frames are superimposed on the LO. Exactly how and when this process occurs remains to be established. The data from the sentence-picture verification task are at least suggestive that the process takes some time to complete, and may occur after the spatial relation depicted in the sentence has been tested against the scene being described.

The results achieved in this thesis are also particularly challenging for more traditional views of spatial language which maintain that the function of spatial language is to narrow the search for an object by locating the object in relation to a second known object (Landau & Jackendoff, 1993; Regier & Carlson, 2001; Talmy, 2000) - relegating converseness to an unnecessary role. We have already seen that information conveyed by a spatial description goes beyond the simple position of the objects and in line with functional geometric framework (Coventry & Garrod, 2004), spatial language is taken to communicate information about the most informative spatial relations present in the scene being described. Consideration of other spatial relations in the scene not specified by the sentence to be evaluated, as is the case with converseness, is a stronger test of the wider view of spatial language proposed in the functional geometric framework. For example, talking about the position of an object A in a scene with reference to another object B carries with it the assumption that the position of object B is important also. And the position of that object B can only be gauged with reference to the position of object A in the scene if there are only two objects present. Hence one can argue that it is not by chance that languages such as English cluster many lexical items into pairs so that language can reflect the multiple relations that hold between objects. Speakers have a duty to avoid statements that are informationally weaker than their knowledge of the world and the language allows. And as a consequence people are sensitive to the logical properties of language when they comprehend it and test out whether converseness holds in order to assess the felicitousness of a given spatial expression.

The findings discussed in this thesis have also implications for the Mental Model Theory (Byrne & Johnson-Laird, 1989; Johnson-Laird, 1983) that claims that people build mental representations useful to apprehend our world and reason about it. However the choice of models constrains the way we can reason about objects and affects the reasoning we can carry out. As a consequence, more complex tasks require more complex models, making the manipulation of the entire representation more difficult. The results reported here fit nicely with this view, showing that scenes where more complex models apply (i.e., those where converseness does not hold) reduces the informativeness of the relative spatial description. In fact spatial expressions that identify unique, single models of the world, will lead to decreased cognitive effort for the hearer and, as a result, are comprehended most easily and the sentences that describe it are judged as more appropriate. According to this theory, we should find that people produce spatial descriptions more easily for spatial arrays where the models required to represent the entire scene are easily identified.

From a cross linguistic perspective we expect converseness to show the same effect across languages. However, given that we have found converseness to be particularly sensitive to the reference frames available, we can expect different results for those languages that use specific reference frames. For example speakers of Mopan language use an intrinsic reference object only (Levinson, 2003); this would make the converseness effect even stronger for the speakers of this language given that contrasting descriptions are generated from that perspective. On the other hand, speakers of Guugu Yimithirr assign only the absolute reference frames (Levinson, 2003) and therefore should be less sensitive to the effect of converseness. It would be interesting to test our hypotheses within these languages.

The current work has also some implications for spatial language research generally. To start with we have found evidence in support of the Functional-Geometric Framework (Coventry & Garrod, 2004) showing that people draw inferences that go beyond the simple geometric information carried in a spatial description. In addition our findings have some impact for a developmental perspective as well; we know from literature that children learn how to use their first spatial prepositions (*in* and *on*) at the age of 2 whereas the projective prepositions (*above, in front of*) only appear a few years later. In the light of the results we achieved in this thesis, it is noteworthy that the first prepositions, the easiest to learn, with those that do not allow people to use converseness to test informativeness. On the other hand, projective prepositions, perhaps the most inferentially complex, are those which are required much later.

In the present work we have made extensive use of the picture-sentence rating task. This methodology is an "off-line" procedure and therefore is exposed to the criticism that participants may have been encouraged to use strategies. However, we have shown that the effect of converseness on the informativeness for a given spatial description is also present in a sentence-picture verification task, that is an "on-line" paradigm. In addition the most common strategies that participants may have used concerns the possibility to look at one object only Logan & Compton (1996). If this is the case we can exclude the possibility they focused on the LO only because spatial language apprehension process requires to allocate them some attention to the RO first (Logan, 1994). However we cannot exclude participants focused on RO only, but in this case the manipulation of the orientation of the LO should not have any effect. Nevertheless in almost all the experiments we showed that was not the case.

The effects of converseness we have reported in this thesis have consequences for the apprehension of spatial language. In fact almost all experiments employed sentence-picture acceptability rating tasks that are considered an alternative methodology to investigate spatial apprehension process (Carlson-Radvansky & Irwin, 1993). In summary the appropriateness of a spatial preposition to describe a scene also depends on whether the converseness holds or not for a given spatial array. This suggests that people apply this inference in order to decide whether the description is suitable or not in describing the scene. In a production task however, where the importance of producing an informative utterance, according to the pragmatic principles, is even more important, we would expect that the applicability of converseness will be even more compelling than in a comprehension task. For production the fact that people draw inferences such as converseness emphasises the importance of pragmatic principle of communication, in which the speaker attempts to produce the most informative description in order to maximise the informativeness of the spatial description. For comprehension, the effect of converseness reflects the speaker elaboration of incoming information and therefore the inference of converseness should have less impact in such process.

The fact that the methodologies used in this thesis are considered suitable to test spatial apprehension process (Carlson-Radvansky & Irwin, 1993, 1994; Carlson-Radvansky & Logan, 1997), it would be worthwhile to investigate the effect of converseness within a more natural setting such as a production task. With this methodology we are able to get a measure of the time people require to describe a scene, which should reflect two central processes of spatial language production: testing the model that best represents the spatial relations in the scene and selecting the most informative model. In accordance with our findings we would expect that scenes where converseness holds to be more informative and therefore selected more quickly than scenes where converseness does not hold. In doing that, we would have further confirmation that people try to produce the most informative description in order to fulfil the pragmatic rules of conversation.

In conclusion, there are many aspects of language that go beyond simple geometric information; among these, we have shown that people apply converseness in order to test for the most informative description that maximises the linguistic exchange. Furthermore, we have shown that people consider the context in which the objects occur, again in order to produce the most informative description.

Appendix A

Mono oriented objects

Intrinsic Axis Objects (IA)

- box
- cat
- chicken
- hat
- monkey
- pan
- squirrel
- vase

Non Directional Axis Objects (NDA)

- barrel
- drum
- hourglass

- ladder
- pen
- stick
- tube
- wand

No Axis Objects (NA)

- cog-wheel
- fan
- football
- porthole
- rock
- shield
- ship's wheel
- wheel

Appendix B

Polyoriented objects

- apple
- carrot
- peach
- courgette
- pepper
- pineapple
- pumpkin
- strawberry

Appendix C

Tables of means

Table 9-A

Results of the 4-way ANOVA for Experiment 1: (1) = Proximity (far vs. near), (2) = Superior vs. Inferior prepositions, (3) = Prepositions Set, (4) = Orientation of the LO ("vertical vs. upside down").

Source	df Effect	df Error	MS Error	F	Significance
1	1	31	180.31	56.92	***
2	1	31	5.24	9.41	**
3	1	31	58.13	17.27	***
4	1	31	12.15	2.9	ns
12	1	31	0.83	3.78	ns
13	1	31	3.41	9.01	**
23	1	31	9.07	5.81	*
14	1	31	0.26	0.95	ns
24	1	31	0.54	2.31	ns
34	1	31	0.4	2.25	ns
123	1	31	0.15	8.11	**
124	1	31	0.05	0.14	ns
134	1	31	0.21	0.62	ns
234	1	31	0.01	0.02	ns
1234	1	31	1.61	1.63	ns

Note: ns $p > .05$
* $p < .05$
** $p < .01$
*** $p < .001$

Table 9-B

Results of the 4-way ANOVA for Experiment 1: (1) = Proximity (far vs. near), (2) = Superior vs. Inferior prepositions, (3) = Prepositions Set, (4) = Orientations of the LO ("pointing at" vs. "pointing away").

Source	df Effect	df Error	MS Error	F	Significance
1	1	31	224.79	89.15	***
2	1	31	5	8.16	**
3	1	31	38.91	10.88	**
4	1	31	0.77	5.16	*
12	1	31	0.02	0.05	ns
13	1	31	1.32	3.6	ns
23	1	31	2.23	1.23	ns
14	1	31	0.03	0.16	ns
24	1	31	8.76	3.76	*
34	1	31	0.01	0.002	ns
123	1	31	0.31	1.04	ns
124	1	31	0.01	0.08	ns
134	1	31	0.15	0.73	ns
234	1	31	0.71	3.01	ns
1234	1	31	0.01	0.004	ns

Note: ns $p > .05$
* $p < .05$
** $p < .01$
*** $p < .001$

Table 10-A

Results of the 5-way ANOVA for Experiment 2: (1) = Prepositions Set, (2) = RO types, (3) = Superior vs. Inferior preposition, (4) = Proximity (near vs. far), (5) = Orientation of the LO ("vertical" vs. "upside down").

Source	df Effect	df Error	MS Error	F	Significance
1	1	22	82.63	5.51	*
2	2	44	0.8	2.1	ns
3	1	22	5.35	17.41	***
4	1	22	432.14	68.81	***
5	1	22	32.17	8.67	**
12	2	44	0.76	2.01	ns
13	1	22	0.01	0.04	ns
23	2	44	0.97	2.83	ns
14	1	22	12.61	1.87	ns
24	2	44	0.52	1.78	ns
34	1	22	0.03	0.228	ns
15	1	22	4.61	1.242	ns
25	2	44	0.18	0.409	ns
35	1	22	0.72	3.335	ns
45	1	22	1.86	6.34	*
123	2	44	0.3	0.91	ns
124	2	44	0.2	0.8	ns
134	1	22	0.2	1.74	ns
234	2	44	0.01	0.05	ns
125	2	44	0.51	1.1	ns
135	1	22	0.78	3.07	ns
235	2	44	0.1	0.15	ns
145	1	22	0.01	0.01	ns
245	2	44	0.32	1.65	ns
345	1	22	0.12	0.31	ns
1234	2	44	0.3	1.28	ns
1235	2	44	0.1	0.14	ns
1245	2	44	0.1	0.88	ns
1345	1	22	0.01	0.01	ns
2345	2	44	0.23	0.53	ns
12345	2	44	0.16	0.41	ns

Note: ns $p > .05$
* $p < .05$
** $p < .01$
*** $p < .001$

Table 10-B

Results of the 5-way ANOVA for Experiment 2: (1) = Prepositions Set, (2) = RO types, (3) = Superior vs. Inferior preposition, (4) = Proximity (near vs. far), (5) = Orientation of the LO ("pointing at" vs. "pointing away").

Source	df Effect	df Error	MS Error	F	Significance
1	1	22	47.35	2.05	ns
2	2	44	0.14	0.453	ns
3	1	22	9.99	12.93	***
4	1	22	451	64.9	***
5	1	22	0.01	0.032	ns
12	2	44	0.84	2.72	ns
13	1	22	1.19	1.54	ns
23	2	44	0.24	1.02	ns
14	1	22	9.86	1.41	ns
24	2	44	1.26	4.26	*
34	1	22	0.06	0.333	ns
15	1	22	0.39	1.19	ns
25	2	44	0.02	0.114	ns
35	1	22	19.19	5.31	*
45	1	22	1.09	3.43	ns
123	2	44	0.1	0.409	ns
124	2	44	0.03	0.09	ns
134	1	22	0.11	0.61	ns
234	2	44	0.39	1.98	ns
125	2	44	0.01	0.05	ns
135	1	22	0.06	0.01	ns
235	2	44	1.25	3.78	*
145	1	22	0.53	1.67	ns
245	2	44	0.01	0.04	ns
345	1	22	3.17	6.03	*
1234	2	44	0.08	0.41	ns
1235	2	44	0.15	0.46	ns
1245	2	44	0.44	1.97	ns
1345	1	22	0.01	0.001	ns
2345	2	44	1.05	7.11	**
12345	2	44	0.22	1.48	ns

Note: ns $p > .05$
* $p < .05$
** $p < .01$
*** $p < .001$

Table 11-A

Results of the 4-way ANOVA for Experiment 3: (1) = *Above* vs. *Below*, (2) = Proximity (near vs. far), (3) = Orientations of the LO ("vertical" vs. "pointing at"), (4) = Orientations of the RO ("vertical" vs. "pointing at").

Source	df Effect	df Error	MS Error	F	Significance
1	1	24	0.12	0.06	ns
2	1	24	44.89	18.52	***
3	1	24	14.44	10.48	**
4	1	24	10.24	6.34	**
12	1	24	3.61	3.03	ns
13	1	24	7.29	7.19	*
23	1	24	0.42	0.443	ns
14	1	24	10.24	5.2	**
24	1	24	1.56	1.21	ns
34	1	24	0.01	0.014	ns
123	1	24	2.1	1.657	ns
124	1	24	0.2	0.195	ns
134	1	24	0.12	0.14	ns
234	1	24	0.09	0.06	ns
1234	1	24	0.64	0.412	ns

Note: ns p >.05
* p <.05
** p <.01
*** p <.001

Table 11-B

Results of the 4-way ANOVA for Experiment 3: (1) = *Above* vs *Below*, (2) = Proximity (near vs. far), (3) = Orientation of the LO (90° pointing away vs. 90° pointing towards), (4) = Orientation of the RO (90° pointing away vs. 90° pointing towards).

Source	df Effect	df Error	MS Error	F	Significance
1	1	24	0.68	0.22	ns
2	1	24	53.66	23.83	***
3	1	24	2.03	1.57	ns
4	1	24	0.6	0.46	ns
12	1	24	1.5	1.36	ns
13	1	24	0.33	0.18	ns
23	1	24	0.77	.57	ns
14	1	24	1.43	1.94	ns
24	1	24	0.46	0.35	ns
34	1	24	0.08	0.06	ns
123	1	24	4.52	3.99	ns
124	1	24	0.53	0.54	ns
134	1	24	0.03	0.01	ns
234	1	24	0.28	0.4	ns
1234	1	24	0.05	0.03	ns

Note: ns $p > .05$
* $p < .05$
** $p < .01$
*** $p < .001$

Table 12-A

Results of the 4-way ANOVA for Experiment 4: (1) = Superior vs. inferior prepositions, (2) = Preposition set, (3) = Proximity (near vs. far), (4) = Orientation of the LO ("vertical" vs. "upside down").

Source	df Effect	df Error	MS Error	F	Significance
1	1	26	1.34	2.51	ns
2	1	26	55.4	12.63	***
3	1	26	274	64.12	***
4	1	26	1.94	.57	ns
12	1	26	2.19	1.93	ns
13	1	26	2.16	8.49	**
23	1	26	4.14	12.08	***
14	1	26	0.39	2.07	ns
24	1	26	0.01	0.04	ns
34	1	26	0.01	0.02	ns
123	1	26	0.25	0.64	ns
124	1	26	0.08	0.29	ns
134	1	26	1.28	4.35	*
234	1	26	0.01	0.001	ns
1234	1	26	0.35	1.49	ns

Note: ns $p > .05$
* $p < .05$
** $p < .01$
*** $p < .001$

Table 12-B

Results of the 4-way ANOVA for Experiment 4: (1) = Superior vs. inferior prepositions, (2) = Preposition set, (3) = Proximity (near vs. far), (4) = Orientation of the LO ("pointing at" vs. "pointing away").

Source	df Effect	df Error	MS Error	F	Significance
1	1	26	5.93	11.54	**
2	1	26	57.9	13.08	**
3	1	26	376	90.06	***
4	1	26	1.29	7.16	**
12	1	26	1.09	2.35	ns
13	1	26	0.27	1.68	ns
23	1	26	2.23	7.03	**
14	1	26	6.29	1.42	ns
24	1	26	0.01	0.025	ns
34	1	26	0.01	0.077	ns
123	1	26	0.56	3.76	ns
124	1	26	0.027	0.172	ns
134	1	26	0.01	0.027	ns
234	1	26	0.32	1.54	ns
1234	1	26	0.02	1.42	ns

Note: ns $p > .05$
* $p < .05$
** $p < .01$
*** $p < .001$

Table 13-A

Results of the 2-way ANOVA for Experiment 5 for both correct TRUE and correct FALSE trials: (1) = *Above* vs. *Below*, (2) = Orientation of the LO ("vertical" vs. "upside down").

TRUE

Source	df Effect	df Error	MS Error	F	Significance
1	1	23	18595	7.48	*
2	1	23	378	0.001	ns
12	1	23	3125	0.173	ns

FALSE

Source	df Effect	df Error	MS Error	F	Significance
1	1	23	93900	1.875	ns
2	1	23	41200	1.062	ns
12	1	23	7525	0.297	ns

Note: ns $p > .05$
* $p < .05$
** $p < .01$
*** $p < .001$

Table 13-B

Results of the 2-way ANOVA for Experiment 5 for both correct TRUE and correct FALSE trials: (1) = *Above* vs. *Below*, (2) = Orientation of the LO ("pointing at" vs. "pointing away").

TRUE

Source	df Effect	df Error	MS Error	F	Significance
1	1	23	6109	0.54	ns.
2	1	23	187076	6.564	*
12	1	23	100148	6.13	*

FALSE

1	1	23	260000	10.61	**
2	1	23	190000	.64	ns
12	1	23	250000	11.21	**

Note: ns p >.05
* p <.05
** p <.01
*** p <.001

Table 14

Results of 2-way ANOVA for Experiment 6 on TRUE trials: (1) = Location for the LO (right vs. left), (2) = *On* vs. *To*, (3) = Converseness.

Source	df Effect	df Error	MS Error	F	Significance
1	1	27	15.04	23.22	***
2	1	27	.08	.341	ns
3	1	27	30.27	14.74	***
12	1	27	.24	1.41	ns
13	1	27	23.06	10.95	**
23	1	27	.06	.291	ns
123	1	27	.18	.482	ns

Note: ns $p > .05$
* $p < .05$
** $p < .01$
*** $p < .001$

Table 15.

Results of the 4-way ANOVA for Experiment 7: (1) = Left vs. Right, (2) = Horizontal location of the LO, (3) = Vertical location of the LO, (4) = Converseness.

Source	df Effect	df Error	MS Error	F	Significance
1	1	28	.023	.035	ns
2	1	28	1.59	2.62	ns
3	1	28	15.72	6.73	*
4	1	28	3.19	8.76	**
12	1	28	640.04	55.22	***
13	1	28	1.7	3.48	ns
23	1	28	.26	.75	ns
14	1	28	1.59	3.45	ns
24	1	28	10.41	31.5	***
34	1	28	.155	.39	ns
123	1	28	2.59	3.45	ns
124	1	28	.035	.051	ns
134	1	28	5.67	11.43	**
234	1	28	2.27	6.49	*
1234	1	28	1.43	4.54	*

Note: ns $p > .05$
* $p < .05$
** $p < .01$
*** $p < .001$

Table 16

Results of the 3-way ANOVA for experiment 8: (1) = *In front of* vs. *Behind*, (2) = Proximity (near vs. far), (3) = Converseness.

Source	df Effect	df Error	MS Error	F	Significance
1	1	19	0.71	7.96	**
2	1	19	0.97	.03	ns
3	1	19	13.75	8.07	*
12	1	19	0.26	.51	ns
13	1	19	0.89	3.66	ns
23	1	19	0.1	2.47	ns
123	1	19	0.14	.03	ns

Note: ns p >.05
* p <.05
** p <.01
*** p <.001

Table 17

Results of the 4-way ANOVA for Experiment 9: (1) = LO-I distance, (2) = LO-RO distance, (3) = *Far* vs. *Near*, (4) = Presentation order.

Source	df Effect	df Error	MS Error	F	Significance
1	2	58	1.31	3.49	*
2	1	29	0.58	10.13	**
3	1	29	13.12	0.9	ns
4	4	58	0.26	1.96	ns
12	4	58	0.35	4.47	*
13	4	58	4.31	19.31	***
23	1	29	28.84	127.88	***
14	4	116	0.25	1.6	ns
24	2	58	0.24	1.38	ns
34	2	58	0.31	6.75	**
123	2	58	0.48	18.08	***
124	4	116	0.19	1.31	ns
134	4	116	0.38	2.44	ns
234	2	58	0.29	1.86	ns
1234	4	116	0.18	4.49	**

Note: ns p >.05
* p <.05
** p <.01
*** p <.001

Table 18

Results of the 3-way ANOVA for Experiment 10: (1) = RO-LO distance, (2) = LO-I distance, (3) = *Far* vs. *Near*.

Source	df Effect	df Error	MS Error	F	Significance
1	1	27	0.33	6.03	*
2	2	54	0.4	2.01	ns
3	1	27	1.73	52.35	***
12	2	54	0.26	0.42	ns
13	1	27	4.87	86.2	***
23	2	54	0.67	0.89	ns
123	2	54	0.35	0.61	ns

Note: ns p >.05
* p <.05
** p <.01
*** p <.001

Appendix D

List of Objects Used in Experiment 8

- frog
- pigeon
- bear
- penguin
- dog
- horse
- elephant
- man

Appendix E

Distance Calculation

The following formulae have been used to calculate the positions of the objects in Experiment 9. Coordinates for the three objects were (a,b) for object1 (c,d) for obejct2 and (x,y) for object3. The distance between object1 (a,b) and object2 (c,d) is called R, whereas the distance between object2 (c,d) and object3 (x,y) is called P. In order to calculate the coordinate of object3 (x,y) considering the relative coordinates for object1 and object2, we used the following formulas:

$q = \frac{(b-d)}{(c-a)}$

$s = \frac{(R^2-P^2-a^2+c^2-b^2+d^2)}{2(c-a)}$

$\alpha = (q^2) + 1$

$\beta = ((q * s) - (a * q) - b)$

$\gamma = ((s - a)^2) + (b^2 - R^2)$

$y = \frac{(-\beta)+\sqrt{(\beta^2-(\alpha*\gamma))}}{\alpha}$

$x = (q * y) + s.$

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