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Spatial language and spatial representation: a cross-linguistic comparison

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Abstract

We examined the relationship between spatial language and spatial memory by comparing native English, Japanese, and Korean speakers' naming of spatial locations and their spatial memory for the same set of locations. We focused on two kinds of spatial organization: axial structure of the reference object, and contact/support with respect to its surface. The results of two language (naming) tasks showed similar organization across the three language groups in terms of axial structure, but differences in organization in terms of contact/support. In contrast, the results of two memory tasks were the same across language groups for both axial structure and contact/support. Moreover, the relationship between spatial language and spatial memory in the two sets of tasks did not show a straightforward isomorphism between the two systems. We conclude that spatial language and spatial memory engage the same kinds of spatial properties, suggesting similarity in the foundations of the two systems. However, the two systems appear to be partially independent: the preservation of particular spatial properties was not mandatory across languages, nor across memory tasks, and cross-linguistic differences in spatial language did not lead to differences in the non-linguistic encoding of location. We speculate that the similarity in linguistic and non-linguistic representations of space may emerge as a functional consequence of negotiating the spatial world.

Keywords: Spatial language; Spatial representation; Cross-linguistic comparison

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1. Introduction

This paper concerns the relationship between spatial language and non-linguistic spatial representations in memory. The nature of the correspondence between these two systems of knowledge could take one of several forms: spatial language could reflect universal non-linguistic spatial representations (Clark, 1973; Landau & Jackendoff, 1993; Talmy, 1983), non-linguistic representations could be molded by the specific language which a person learns (Levinson, 1996; Lucy, 1992; Whorf, 1956), or each system might play a role in shaping the other (Imai & Gentner, 1997). Moreover, the correspondences between the two spatial systems might be complete or only partial. In order to explore these issues, we ask how native speakers of different languages express spatial relationships between pairs of objects, and how they encode these same relationships in a non-linguistic memory task.

1.1. Background and rationale

At the heart of questions about the relationship between language and cognition lie two contrasting views. One is that universals of non-linguistic spatial representation shape spatial language. This view assumes that the meanings expressed by languages must reflect conceptual entities and relationships that are generally important in human cognition. Foundational concepts – such as space – allow us to talk about the world around us and our experiences in it. Because we all live in the same physical world, our representations of space might well be universal. Furthermore, it is plausible that spatial language has universal elements that rest on these representations (Clark, 1973; Jackendoff, 1983; Landau & Jackendoff, 1993; Talmy, 1983).

A second view is that differences in spatial language shape non-linguistic spatial representations. This view is based on compelling observations of variability in how languages encode space, and is often associated with the work of Benjamin Whorf (1956) in the related domain of temporal cognition. Whorf claimed that the Hopi language encodes the dimension of time quite differently from Western languages. As a consequence, Whorf suggested, Hopi speakers possess a different concept of time than that of speakers of Western languages (Lee, 1996).[1] Extending this argument to the domain of space, variation in spatial language might shape non-linguistic spatial representations.[2]

These two views – that there must be universal non-linguistic foundations for spatial language, and that there must be language-specific effects on spatial repre-

[1] Lee (1996), among others, has argued that the point made by Whorf (1956) was not that Hopi speakers were unable to refer to temporal events at all, as some have said, but rather that the Hopi language invokes a completely different concept of time than that of speakers of Western languages. Specifically, Whorf's claim was that while Western languages refer to time on a continuum, Hopi makes reference to time in discrete bundles, intimately tied to space (akin to the sense of time invoked in quantum physics).

[2] Logically, there are two additional forms that the relationship between spatial language and non-linguistic spatial cognition could take: universals of spatial language could lead to universals of non-linguistic spatial cognition, or variation in non-linguistic spatial cognition could lead to variation in spatial language. We will focus our attention on the views presented in the main text, because these two make clearly opposed predictions, and have served as the main focus of recent research.

sentations – have recently taken on new prominence in the face of discoveries that languages vary widely in how they encode space (Bowerman, 1996; Brown & Levinson, 1993; Lucy, 1992; Pederson et al., 1998). For example, the English word "on" encodes a relationship that is encoded by two separate words in German (and other languages): German "an" refers to instances of support involving attachment, such as "the painting **on** the wall" or "the tab **on** the soda can", whereas "auf" refers to support that can occur without attachment, as in "the cup **on** the table". English (among other languages) does not draw this particular distinction in its inventory of basic spatial terms,[3] and hence English differs from German in the lexical encoding of these particular spatial relations. In other cases, English makes distinctions not found in the basic spatial lexicons of other languages. For example, English obligatorily distinguishes between relationships in which one object is "on" another and relationships in which one object is "above" the other. However, both of these relationships can be encoded by the single term "ue" (literally, "top") in Japanese.

Beyond these examples, there are cases in which the spatial distinctions that are made in English appear to be orthogonal to the distinctions made by other languages. In one study, Bowerman and Choi (1994) found that for a variety of joining actions, English speakers focused on the distinction between support ("put on") and containment ("put in"), while Korean speakers focused on tightness of fit. For instance, although English speakers differentiated "putting a cap **on** a pen" from "putting a cassette **in** a case", Korean speakers used the verb "kkita" – meaning "to fit objects together tightly" – to describe both. At the same time, while English speakers used "in" for both the latter example and "putting a doll **in** a bathtub", Korean speakers contrasted "kkita" with "nehta", which means "to put objects together loosely". Thus, a natural encoding to the English speaker may be relatively unnatural in the lexicon of another language, and vice versa. Another example in which languages systematically covary is discussed by Talmy (1985, 1991), who distinguishes between two broad typological patterns of describing motion events. Satellite-framed languages (including English) canonically encode path (e.g. "in", "out") outside of the verb, while incorporating manner (e.g. "running") within the verb. On the other hand, verb-framed languages (including Spanish and Turkish) place path within the verb, and manner outside of the verb. So while an English speaker would canonically say "She **ran out** of the room", a Spanish or a Turkish speaker would say the equivalent of "She **exited** the room **running**". In studies of spontaneous production of motion verbs, Slobin and colleagues (Berman & Slobin, 1994; Ozcaliskan & Slobin, 1999) have found that as early as 3 years of age, speakers of

[3] In this paper, a basic spatial term is defined as a term with spatial content that is monolexemic, and that is used obligatorily in certain situations in a given language. To be monolexemic, the term's meaning must not be predictable from the meanings of its parts (Berlin & Kay, 1969). For example, "top left" is not a basic term, since it can be decomposed into "top" and "left" to discover its meaning. Our notion of basic terms is related to the "lexical concepts" of Fodor (1981), which are monomorphemic predicates that he contrasts with "phrasal concepts", whose meanings are derived from several lexical concepts in conjunction (p. 260). For the purposes of this paper, we draw no distinction between an expression being monolexemic and being monomorphemic.

satellite-framed languages focus more on the manner of motion for a given scene, while speakers of verb-framed languages focus more on the path of motion for the same scene (see also Ozyurek & Kita, 1999). Slobin (1996) has argued that as we speak, the dominant patterns of our languages cause us to attend to certain aspects of the world and not to others – "thinking for speaking".

Such findings have naturally led to the question of whether cross-linguistic differences lead to corresponding non-linguistic differences. One test-bed for such inquiry has been the domain of color (Berlin & Kay, 1969; Brown & Lenneberg, 1954; Davidoff, Davies, & Roberson, 1999; Heider, 1972; Heider & Olivier, 1972; Lantz & Stefflre, 1964; Stefflre, Castillo Vales, & Morley, 1966). Heider and Olivier (1972) carried out one often cited study, examining the structure of color naming and the structure of color memory across two groups whose native color lexicons differed. Native speakers of English, which has 11 basic color terms, were compared to native speakers of Dani from Irian Jaya, Indonesia, whose language includes only two basic color terms ("mili" and "mola", corresponding roughly to "dark" and "light"). Participants were given naming tasks in which they named color chips, and memory tasks in which they remembered which colors they had seen. Despite cross-linguistic differences in the color naming task, Heider and Olivier found that the color memory categories were highly similar across language groups, indicating that even quite substantial differences in the structures of the two color lexicons did not result in changes to people's memory for color.[4]

More recently, Davidoff et al. (1999) have reported evidence quite different from that of Heider and Olivier. Davidoff and colleagues studied color naming and color memory in the Berinmo of Papua New Guinea. They noted that although Dani (studied by Heider and Olivier) has only one color distinction, it is consistent with a distinction that English makes – that is, Dani categories are supersets of English categories. In contrast, the Berinmo vocabulary has categories that cut across English category boundaries, thus possibly providing a stronger test of the effects of language on color memory. Using Heider and Olivier's method, Davidoff and colleagues found that Berinmo color memory was consistent with Berinmo color terms, and accordingly not consistent with English speakers' color memory. Thus, these findings stand in direct opposition to those of Heider and Olivier, and support the idea that cross-linguistic differences might change the organization of color in memory.

This body of work on color has set the stage for recent research on cross-linguistic differences in the coding of space, and the consequences of these differences for spatial cognition. Spatial categories would seem to present a quite natural candidate for shaping by language. First, spatial relationships are represented in multiple brain systems, possibly organized by functional considerations such as perception and action or by computationally different domains such as navigation and object recognition (Gallistel, 1990; Milner & Goodale, 1996). Thus, spatial representation in some systems could be affected by language, whereas in others it could be insulated

[4] Heider and Olivier (1972) defined color memory categories by patterns of memory errors. That is, color tokens which were highly confusable were considered to be members of the same category.

from language. Second, spatial relationships play an important role in higher cognition, such as metaphor, analogy, and imagery (Gentner, 1977; Kosslyn, 1980), and different kinds of spatial structure may be required for these different functions. Finally, many aspects of spatial representations appear to undergo substantial development. The use of spatial representations in tasks ranging from symbolic use to explicit understanding of metric systems develops substantially over the first 6 years and possibly beyond (DeLoache, 1987; Huttenlocher & Presson, 1979; Newcombe & Huttenlocher, 1992; Silberstein & Spelke, 1995). The protracted time course for development and the extensive use of spatial representations in higher cognitive functions suggests the plausibility of learning effects and, particularly, effects of the learning of spatial language on the organization of non-linguistic spatial representations. Several recent studies provide intriguing evidence on this front.

1.2. Non-linguistic spatial representations correspond to spatial language

Hayward and Tarr (1995) sought evidence that foundational aspects of non-linguistic spatial representations could be reflected in spatial language, resulting in a correspondence between the two systems in the spatial properties they encode. They noted that an object's location is defined with respect to a reference object, in both linguistic and non-linguistic representation. Furthermore, the axes of the reference object appear to play an important role in assigning location, in tasks ranging from strictly linguistic judgments of the acceptability of terms such as "above" and "below" (Carlson-Radvansky & Irwin, 1993) to attentional tasks involving the detection of objects relative to each other (Logan, 1995). In order to determine the importance of axial structures for language and memory, Hayward and Tarr examined the way native English speakers label an object's location, and they compared this to people's accuracy in remembering those same locations. In a series of experiments, they found that those locations which were most consistently named by the basic spatial terms of English (e.g. "above", "below", "right", "left") were also the locations that were remembered best.

In their language tasks, Hayward and Tarr asked participants either to describe the locations of figure objects (the objects that are located) relative to a reference object, or to rate the applicability of a set of basic spatial terms as descriptors of those locations. They found that vertical terms (such as "above" and "below") were most often elicited and received the highest applicability ratings along the vertical axis of the reference object; likewise, horizontal terms (such as "left" and "right") were most preferred along the reference object's horizontal axis.[5]

In corresponding memory tasks, Hayward and Tarr assessed people's memory for the same locations that had been used in the language task. Participants saw the same series of scenes as in the language experiments, again depicting figure and reference object relationships. After each scene disappeared, they were asked either to judge

[5] In this experiment and in others presented in this paper, the scenes that participants saw did not have axes drawn in; rather, axes are conjectured to be part of the participant's mental representation of the scene.

whether a second scene showed the objects in the same spatial relationship as the first, or to place the figure object in the location relative to the reference object where it had appeared earlier. The results were analogous to those of the language task: accuracy was highest when the figure object lay on one of the axes extending from the reference object.

The parallel in the structures elicited by language and memory tasks among English speakers is consistent with three contrasting possibilities, which could be tested by carrying out a cross-linguistic replication of Hayward and Tarr's study. First, non-linguistic representations might serve as an organizational basis for spatial language. Second, the two systems might independently draw on the same set of spatial properties (see Crawford, Regier, & Huttenlocher, 2000, for discussion of this possibility). If either of these were true, we would expect to find parallels in spatial organization on non-linguistic memory tasks, even among speakers of a language with a spatial lexicon quite different from English. The third possibility is that spatial language shapes non-linguistic spatial representations. If so, cross-linguistic differences in the spatial lexicon should lead to corresponding *differences* in memory for location. The experiments described in this paper accordingly test the third possibility against the other two – if the third possibility is confirmed, it would be evidence for a profound effect of language on non-linguistic cognition; if it is disconfirmed, further work would be necessary to decide between the first and second possibilities.

1.3. Spatial language may shape non-linguistic spatial cognition

A separate series of recent studies (Brown & Levinson, 1993; Pederson et al., 1998) have sought to determine whether differences in spatial language give rise to corresponding non-linguistic differences. In one series of experiments, Brown and Levinson examined variation in the kinds of reference system used by speakers of Dutch and Tzeltal. In Dutch – as in English – terms such as "above", "below", "left", and "right" are appropriate for use with object- or environment-centered frames of reference, whereas "north", "south", "east", and "west" are appropriate for use with geographic frames of reference. Different terms are used depending on what frame of reference is adopted by the speaker. For example, in English the position of a particular bicycle may be described either as "to the north of the tree" using an "absolute" (i.e. geographical) system, or "to the left of the tree" using a "relative" (i.e. object- or environment-centered) system. However, these different reference systems are generally used in different contexts. For small layouts, it is unacceptable to use the geographic system, hence the oddity of "*The bowl is to my east", compared to "The bowl is to my left". Generally, the geographic reference system in English – and in Dutch – is reserved for relationships on the scale of bicycles and trees.

In contrast, speakers of Tzeltal, a Mayan language spoken in Chiapas, Mexico, use an "absolute" system in all cases except when two objects are contiguous; in that case, speakers use the "relative" system. Thus, the native speaker of Mayan would find it perfectly natural to state the equivalent of "The bowl is to the east". Brown and Levinson asked whether this very different usage of reference frames between Dutch and Tzeltal has an effect on the way that people encode spatial relationships in **non-linguistic** tasks. If people speaking Dutch reserve the absolute frame of reference for large layouts, but people speaking Tzeltal use it for a much larger variety of layouts, then there might be differences in the ways that these different groups encode location in non-linguistic tasks. In particular, Brown and Levinson asked whether speakers of Tzeltal might be more inclined to use the absolute frame of reference to encode tabletop arrays, whereas speakers of Dutch might be inclined to use the relative frame of reference.

Brown and Levinson further administered recognition, recall, and transitive inference tasks that could be solved according to either an absolute or a relative frame of reference. The tasks required people to observe the locations of objects and to make judgments about what constituted "the same" spatial arrangement, either by replicating the spatial layout after they had moved or by choosing a drawing that represented the correct layout.[6] Across three experiments, Tzeltal speakers did in fact favor an absolute solution (placing objects north/south of each other), while Dutch speakers favored a relative solution (placing objects left/right of each other). Brown and Levinson concluded that the frame of reference dominant in a participant's language biases the conceptual coding employed by the person in non-linguistic tasks. Pederson et al. (1998) have obtained similar results across a variety of languages, using a close variant on these tasks: participants from languages that pattern with Dutch performed the non-linguistic task like Dutch speakers, while participants from languages that pattern with Tzeltal performed the non-linguistic task like Tzeltal speakers (but see Li & Gleitman, 2000 and our Discussions).

1.4. The present experiments

Several issues arise from the preceding studies. The first concerns the evidence for universal properties of non-linguistic spatial representations and their relationship to spatial language. We first ask whether non-linguistic spatial representations show parallels to spatial language across different languages. If they do, these parallels could reflect the shaping of spatial language by non-linguistic spatial representations. Alternatively, any parallels between the systems could be due to their separately engaging the same spatial properties. Although Hayward and Tarr's studies clearly draw on a plausible aspect of spatial representation – the axial structure of reference objects – it remains to be seen whether this structure, in memory and in language, appears consistently across tasks and across languages that differ somewhat in their lexicon of basic spatial terms.

A second issue is whether fundamental aspects of spatial representation such as axial structure might arise universally, but still co-exist with cross-linguistic effects

[6] The Brown and Levinson (1993) tasks were designed to elicit results characteristic of the reference frame used. Their tasks all involved looking at an array, then turning around to look at a second array: when one turns around, the relative frame is reversed (left becomes right), but the absolute frame is unchanged (north remains north). Responses could follow either of two opposite patterns, according to the frame of reference a participant uses.

of the kind shown by Brown and Levinson. It is possible that spatial language might shape representations invoked by non-linguistic memory tasks; therefore, we ask whether cross-linguistic differences in spatial language lead to differences in spatial memory.

In order to test these possibilities, we examined people's language and memory for the locations of objects in contexts virtually identical to those used by Hayward and Tarr. The Language task required people to label the figure object's location when it appeared in a range of locations around the reference object. The Memory task required people to judge the identity or difference of the spatial relationship they observed over a short memory interval. We focused on two aspects of spatial organization: axial structure (as in Hayward and Tarr), and the role of contact and support provided by the reference object for figures adjacent to it. Using these two properties, we carried out cross-linguistic comparisons between adult native speakers of English and of Japanese (Experiment 1) or Korean (Experiment 2).

These languages form an interesting comparison since they share certain properties in their spatial language, but are quite different in other respects. In particular, English, Japanese, and Korean are all similar in their ability to encode basic spatial terms at locations lying along the four main half-axes of a reference object ("above", "below", "left", and "right" in English). The fact that all three languages do have such basic terms raises the question of whether these terms are used in the same distribution across languages. If the proposed parallel between language and space is universal, we might expect similarities in the structure of the linguistic representations and in the memory representations that arise for these locations, across all three linguistic groups.

English, Japanese, and Korean are also rather different in their resources for encoding the second spatial property we examine – contact with the reference object. In particular, English differs from Japanese and Korean in the way that it encodes contact relationships involving support – either by gravity (in the case of an object on the top of another), or by adhesion (in the case of an object attached to the side or bottom of another). In English, support in all cases can naturally be expressed with the basic term "on". In the case of one object resting on another, as soon as the figure object moves even slightly upwards from the reference object, the figure object must be described as "above" the reference object. Similarly, in the other (adhesion) contexts, once adhesion breaks, the figure object is no longer "on" the reference object; rather it is "to the right/left", or "below", and so forth. In contrast, the distinction between immediate support and non-support is not obligatorily encoded in Japanese or Korean; the same term can be used for locations along an axis that are either in or out of a contact relationship with the reference object. In both Japanese and Korean, there are a number of verbs which can express support, but these are only used in cases for which context specifically calls for such a distinction.

The following sentences describe the scenes in Fig. 1a,b, illustrating the fact that the distinction is obligatory in English (sentences 1a and 1b) but optional in Japanese (sentences 2a and 2b) and Korean (sentences 3a and 3b):

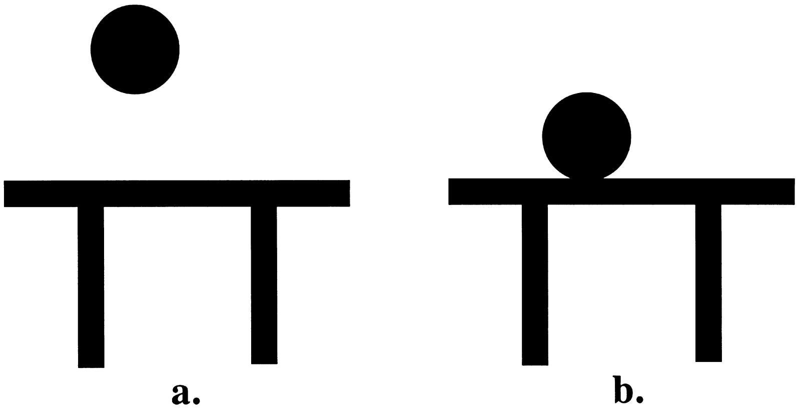

Fig. 1. (a,b) Examples of relationships which are obligatorily distinguished in English but only optionally distinguished in Japanese and Korean.

1a	The cup is ABOVE the table.				
1b	The cup is ON the table.				
2a	Chawan-wa	tsukue-no	UE-ni	[UITE iru]/	aru
	(cup-TOPIC)	(table-GEN.)[a]	(top-LOC.)	(be floating)/	(be)
2b	Chawan-wa	tsukue-no	UE-ni	[NOTTE iru]/	aru
	(cup-TOPIC)	(table-GEN.)	(top-LOC.)	(be on)/	(be)
3a	cup-i	thakca	WI-e	[TTE]	issta
	(cup-TOPIC)	(table)	(top-LOC.)	(floating)	(be)
3b	cup-i	thakca	WI-e	[PUTTE]	issta
	(cup-TOPIC)	(table)	(top-LOC.)	(sticking)	(be)

[a] "GEN." denotes genitive marker; "LOC." denotes locative marker.

Japanese and Korean speakers typically use the base form of sentences 2a and 2b and 3a and 3b, respectively, adding verbs or adverbs such as those in square brackets only when they intend to emphasize that support or lack of support is important to the scene. The key is that the distinction is obligatory in English, so English speakers' attention may be drawn to this distinction every time they use one of these sentences, while Japanese and Korean speakers' attention may only be drawn to the distinction when it is necessary. These differences – like the differences between the Dutch and Tzeltal in the distribution of use of different reference frames – might shape people's memorial representations. In particular, one might expect different memory structures to arise for the native English speakers as compared to either native Japanese or Korean adult speakers. On the other hand, memory structures might remain constant over the three language groups, despite differences in language. If so, this would rule out effects of spatial language on non-linguistic spatial memory, at least in this task context. At the same time, it would be consistent with universal non-linguistic representations that exist side-by-side with linguistic differences.

2. Experiment 1

2.1. Participants

Thirty native Japanese and 30 native English speakers participated, with each group roughly balanced for gender. Within each language group, no participant had been exposed to languages other than their native language before the age of 12.[7] Native English participants were undergraduate and graduate students at the University of California, Irvine, while native Japanese participants were current students or graduates of universities in Japan who were studying at the University of California, Irvine, or the University of Delaware.

2.2. Design and materials

Ten participants from each language group participated in the Language task, and the remainder participated in the Memory task. The design of each task was a modified replication of ones used by Hayward and Tarr (1995), in which a figure object was placed at various distances and angles with respect to a reference object. The principal change was in the stimulus arrays, which were broadened in the present study in order to more closely examine any axial or contact effects. In brief, while Hayward and Tarr's stimuli incorporated only one location adjacent to each side of the reference object, our stimuli were designed so that the figure object could occupy a range of locations adjacent to each of the sides of the reference object.

In both tasks, participants viewed a computer screen; a reference object was displayed at the center of the screen, and a figure object was displayed in another position on the screen. Both objects were positioned according to an overlaid 9×9 grid, in which the reference object occupied the central 3×3 cells and the figure object occupied one of the 72 other cells (see Fig. 2, which shows a sample display superimposed on a grid to indicate target locations; note that participants never saw the grid). Each grid space was 0.5 inches (1.27 cm) square and the area in which objects appeared was 4.5 inches (11.43 cm) square.

[7] All of our Japanese and Korean participants were recent arrivals in the US who had not been exposed to English until the age of 12; all reported that they rarely used English in their free time, even while living in the US. We set the cut-off at age 12 because this age corresponds to the end of what is generally considered to be the critical period for language acquisition (cf. Johnson & Newport, 1989). Therefore, even with substantial exposure to English, participants would not be expected to be able to gain a native-like proficiency in English. In addition, Lucy (1996) has demonstrated that language-specific semantic patterns in naming arise around the age of 8; after the age of 8, participants pattern strongly with the adults of their native language group, suggesting that language-specific patterns may well be in place even earlier than the age of 12.

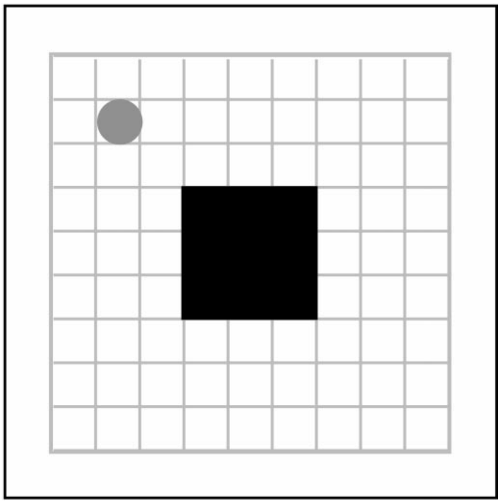

Fig. 2. Example of a display used in Experiment 1. A 9 × 9 grid is superimposed to indicate possible positions of objects (this grid was not present in the display shown to participants).

For each task, there was a total of 72 different figure–reference object relationships, each presented with two different figure objects, a circle and a square, for a total of 144 different scenes. The two different figure objects were presented in separate blocks, counterbalanced for order. The reference object was always a square, as shown in Fig. 2. The 144 scenes were presented in randomized order within blocks. All stimuli appeared on a Macintosh color monitor.

2.3. Procedures

2.3.1. Language task

Participants were asked to view each display and describe the relationship between figure and reference objects by filling in the blank for a sentence of the following form:

The small circle is __________ the large square.[8]

Specifically, participants were instructed to describe the location using a "simple word or phrase", such as "on", "above", "to the left", or "on top of", and to avoid using compass, clock face, or degree of angle answers. These instructions were given in order to elicit the basic terms of each language. After writing their response on an answer sheet, participants pressed a key to bring up the next scene.

[8] The equivalent sentence was used in the Japanese version of the task: "chisai en-wa ookii shikaku __________." (Actual stimuli were printed in Japanese script.) The "be" verb was left out of the Japanese answer sheets because there are two possible be-verbs: "aru" is used alone, while "iru" is used in progressive tenses, as in the English "to be touching". The difference in position of the blank is due to the fact that Japanese follows subject-object-verb order, while English follows subject-verb-object order.

2.3.1.1. Coding of responses. Responses were coded separately for the presence of axial terms and the presence of contact terms. Axial terms were defined as single words, which describe either vertical or horizontal orientation of the figure object with respect to the reference object. These included “above”, “over”, “below”, “top”, “bottom”, “under”, “left”, “right”, and “next (to)”, and their equivalents in Japanese (see Appendix A for a listing of expressions given by each language group). While it was possible that the basic spatial terms of Japanese would not map directly onto those of English, we found that the dictionary equivalents of the English axial terms listed above were in fact the ones that were used by Japanese speakers in greater than 99% of their responses, and that these particular terms were the only means used by Japanese speakers to describe axial relationships, indicating their primary status in the language.

Contact terms were defined as those terms expressing contact or support, and included English “on” (obligatory for many cases of contact) as well as verbs of contact such as “sit” and “touch”, which are optional. Japanese contact terms that occurred included equivalents to the latter verbs as well as additional terms such as “notte” (progressive form of the verb “noru”, meaning “to be on”). Appendix A contains an exhaustive list of contact terms that were used. Note that contact and axial terms were coded independently, so expressions such as “on the top/bottom/left/right” were coded as **both** contact (“on”) and axial (“top”/“bottom”/“left”/“right”). Coding was done by the first author, and reliability checks were done by a native Japanese informant for 100% of the Japanese data and by another native English speaker for 20% of the English data. Intercoder agreement was 98% for the Japanese data and 97% for the English data.

While at least one axial term was used in almost all responses across languages, it turned out that responses often contained more than one axial term, e.g. “to the **top left** of”. Hayward and Tarr (1995) had coded such responses by assuming that the first term mentioned would have priority (in this case, “top”, a vertical term), and this assumption gave rise to orderly results in their study, as well as in preliminary analyses on our data (see Munnich, 1997). However, since lexical ordering rules in Japanese are different from English, applying this rule across the two languages would have resulted in some distinctly spurious patterns.[9] Therefore, the primary analysis of axial terms across both languages considered only simple expressions – those expressions in which a single axial term was

[9] Hayward and Tarr (1995) considered the first (or only) axial term used in a response, based on the assumption that the first term given is primary. In fact, it is often the case that terms that come later in the response are of equal or greater importance than the first term. An example of this is that Japanese participants often described the location of the figure object with compound expressions such as “hidari ue” (“left top”), but never with the reverse order. When queried, participants universally agreed that “ue hidari” (“top left”) is unacceptable in Japanese, and that placing the horizontal term first has nothing to do with its importance. Each language has rules fixing the order of axial terms within complex expressions. For a review of semantic and phonological rules that might be involved, see Cooper and Ross (1975). In any case, it is incorrect to assume that the first term in linear order is primary; hence, we elected to code the pertinent term only when it occurred alone.

applied.[10] As will be seen, the results for English generally replicated Hayward and Tarr using this method.

2.3.2. Memory task

Participants were told that they would view two scenes, separated by a mask, and that they were to judge whether the second scene displayed the same spatial relationship as the first. At the beginning of each trial, participants saw a plus sign (100 ms) for fixation, followed by the first scene (500 ms), a pattern mask (500 ms), the second scene (500 ms), and finally a blank screen, at which point participants pressed either the "z" key with their left hands if the relationships between objects were the same, or the "." key with their right hands if the relationships were different. The key press activated the next trial. Within each trial, the second scene was always displaced by 0.5 inches (1.27 cm) from the absolute position of the first, in order to eliminate any visual persistence.

The 144 different scenes were each presented eight times to each participant. The spatial relationship between the figure and reference objects was identical in half the trials and different in the other half. The four samples in which the figure was moved relative to the reference object were created by translating the figure object one-fourth of a grid space (0.125 inches, 0.32 cm) from its initial position in each diagonal direction. On trials in which the figure object initially contacted the reference object, two of the "different" trials were produced by translating the figure object along the edge of the reference object by the same distance as the other distractors.

2.4. Results and discussion

2.4.1. Language task

The results of the coding were separately analyzed for effects concerning axial terms and those concerning contact terms.

2.4.1.1. Axial terms. Table 1(a–d) shows the proportions of use of basic axial terms for each of the 72 possible figure object locations, with a total possible of two per location (one response for each of the two figure objects). Table 1(a,b) displays proportions of use of vertical terms by Japanese and English speakers, respectively; Table 1(c,d) displays the corresponding proportions of use of horizontal terms. Both

[10] Our decision to analyze simple expressions is based on the fact that the most focal instances of categories tend to be described with the monomorphemic expressions of the language (see, for example, Fodor, 1981; Heider, 1972). Nevertheless, in order to determine whether a different pattern of spatial structure would emerge if we also considered complex expressions, we carried out an analysis of vertical and horizontal terms wherever they were used – whether in simple or in complex expressions. In this analysis, participants showed a complementary pattern of naming to the one reported for simple expressions; that is, they almost always used expressions involving some vertical term (e.g. "above and to the left", "to the left and above", or simply "above") in all locations except those on and adjacent to the horizontal axis. Similarly, they almost always used expressions involving horizontal terms in all locations except those on or adjacent to the vertical axis. Since this pattern is merely the complement of the one we report, it would have been redundant to present it as well.

Table 1
Experiment 1: Proportion of vertical and horizontal terms used by Japanese and English speakers[a]

Row	Column								
	1	2	3	4	5	6	7	8	9
(a) Proportion of vertical terms used by Japanese speakers									
1	0.10	0.10	0.14	0.25	**1.00**	0.25	0.10	0.10	0.10
2	0.10	0.10	0.10	0.21	**1.00**	0.20	0.15	0.10	0.10
3	0.10	0.10	0.10	0.25	**1.00**	0.15	0.10	0.10	0.10
4	0.00	0.00	0.00				0.05	0.00	0.00
5	0.00	0.05	0.00		Reference object		0.00	0.00	0.00
6	0.00	0.00	0.00				0.00	0.05	0.00
7	0.10	0.10	0.10	0.10	**1.00**	0.10	0.10	0.10	0.10
8	0.15	0.10	0.10	0.25	**1.00**	0.20	0.10	0.10	0.10
9	0.10	0.10	0.15	0.20	**1.00**	0.29	0.15	0.10	0.10
(b) Proportion of vertical terms used by English speakers									
1	0.00	0.00	0.05	0.35	**0.95**	0.35	0.00	0.00	0.05
2	0.00	0.00	0.10	0.35	**1.00**	0.35	0.00	0.00	0.00
3	0.00	0.10	0.05	0.25	**1.00**	0.30	0.00	0.00	0.00
4	0.05	0.00	0.00				0.00	0.00	0.00
5	0.00	0.00	0.00		Reference object		0.00	0.00	0.00
6	0.15	0.00	0.00				0.00	0.00	0.00
7	0.00	0.00	0.00	0.25	**0.85**	0.30	0.00	0.00	0.00
8	0.00	0.00	0.00	0.35	**0.90**	0.25	0.15	0.00	0.00
9	0.05	0.00	0.00	0.45	**0.90**	0.44	0.05	0.00	0.00
(c) Proportion of horizontal terms used by Japanese speakers									
1	0.00	0.05	0.00	0.05	0.00	0.05	0.00	0.00	0.00
2	0.05	0.05	0.05	0.00	0.00	0.05	0.00	0.00	0.00
3	0.05	0.10	0.00	0.05	0.00	0.00	0.10	0.10	0.00
4	0.40	0.30	0.30				0.15	0.45	0.40
5	**1.00**	**0.95**	**1.00**		Reference object		**1.00**	**1.00**	**1.00**
6	0.25	0.50	0.20				0.20	0.30	0.30
7	0.00	0.05	0.15	0.05	0.00	0.00	0.05	0.05	0.15
8	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00
(d) Proportion of horizontal terms used by English speakers									
1	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.10
2	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
3	0.10	0.15	0.00	0.00	0.00	0.00	0.00	0.10	0.10
4	0.45	0.40	0.30				0.31	0.40	0.45
5	**0.90**	**1.00**	**0.90**		Reference object		**0.85**	**1.00**	**1.00**
6	0.45	0.50	0.30				0.40	0.55	0.45
7	0.10	0.05	0.00	0.00	0.00	0.00	0.05	0.10	0.10
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
9	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00

[a] Data are listed by the location of the figure object relative to the reference object. The locations are laid out in a 9×9 grid, with the central 3×3 spaces taken up by the reference object (see Fig. 2). Note that locations where an effect is *predicted* are indicated in bold.

language groups used axial terms most frequently when the figure object lay on an (imagined) axis extending from the reference object, and these responses fell off as the figure object's location moved away from the axes. In addition, the use of these basic axial terms appeared almost categorical: use of axial terms was close to 100% along the projected axes, and fell off immediately thereafter. The pattern across languages is extremely similar to that found by Hayward and Tarr (1995).

Separate but analogous analyses were carried out for the vertical and horizontal axial terms. First, we analyzed the proportions of vertical terms elicited across the nine columns, for those locations lying above or below the reference object (i.e. excluding portions of the columns falling in rows 4–6, which intersect the reference object). In order to code distance from the reference object, locations falling directly on the axis (Column 5 in Table 1) were designated as "0" ("zero"), locations one column away (Columns 4 and 6 in Table 1) were designated as "1", locations two columns away (Columns 3 and 7 in Table 1) were designated as "2", etc. (see Fig. 3a). The proportions of vertical terms used for these locations were submitted to a 2 (language) × 5 (distance from axis, 0–4) mixed analysis of variance, with the second factor within-subjects. For horizontal terms, an analogous design was used, with locations falling directly on the horizontal axis designated as "0", locations one row away designated as "1", etc. (see Fig. 3b), and a separate 2 (language) × 5 (distance from axis) analysis of variance was carried out.

Only the effects of distance from axis were reliable (vertical region:

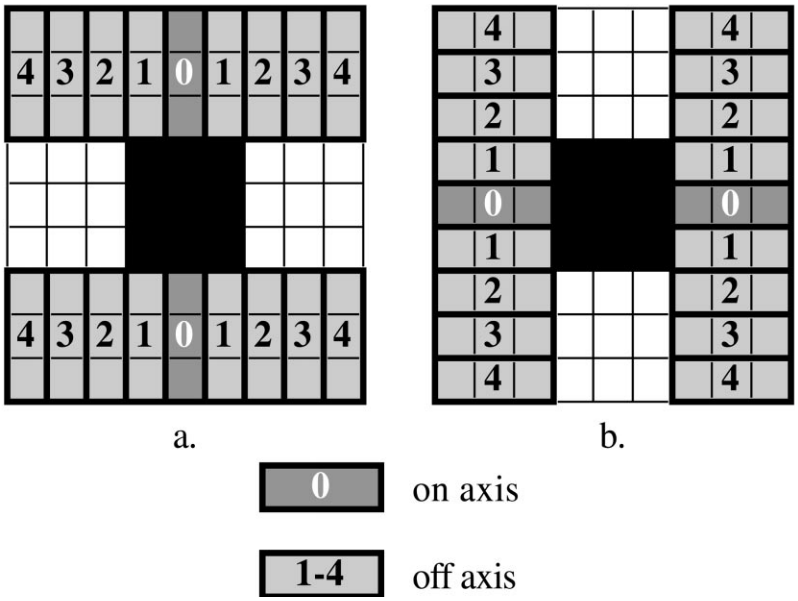

Fig. 3. (a,b) Regions used in analysis of axial effects for both Language and Memory tasks in Experiment 1. Regions tested for vertical effects are shown in (a), and regions tested for horizontal effects are shown in (b).

$F(4, 72) = 84.95$; horizontal region: $F(4, 72) = 112.14$; both $P < 0.01$). Neither the main effects of language nor the interactions of language with distance from axis were significant. Post-hoc tests were carried out between levels of distance from vertical and horizontal axes to determine where the drop-off in use occurred. There were reliable differences between locations on-axis (0) and all rows/columns off-axis (1–4), as well as between distances 1 and 2, but there were no further differences among distances 2, 3, and 4 (Tukey's HSD = 0.15 for both vertical and horizontal terms, $P < 0.05$). Thus, the axial terms were used at the highest (ceiling) levels along the reference object's axis, then dropped sharply until the reference object's edge, after which they showed no further drop. These results suggest strong effects of the reference object's axis, equally for speakers of both languages.

2.4.1.2. Contact terms. Table 2(a,b) displays the mean proportions of use of contact terms by position of the figure object for Japanese and English speakers, respectively. Across the two languages, contact terms were used predominantly in locations adjacent to the reference object. However, there was also a difference in the distribution of the terms across the languages. Japanese speakers' use of contact

Table 2
Experiment 1: Proportion of terms indicating contact used by Japanese and English speakers (by position of figure object)[a]

Row	Column								
	1	2	3	4	5	6	7	8	9
(a) Proportion of terms indicating contact used by Japanese speakers									
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00
2	0.05	0.00	0.00	0.00	0.05	0.00	0.05	0.00	0.00
3	0.05	0.05	0.40	**0.85**	**0.85**	**0.90**	0.40	0.05	0.00
4	0.00	0.00	**0.90**	Reference object			**0.89**	0.05	0.00
5	0.00	0.00	**0.95**				**0.65**	0.00	0.05
6	0.00	0.10	**0.75**				**0.80**	0.05	0.05
7	0.05	0.10	0.45	**0.85**	**0.85**	**0.85**	0.40	0.10	0.05
8	0.05	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.10
9	0.00	0.05	0.00	0.05	0.00	0.00	0.00	0.05	0.00
(b) Proportion of terms indicating contact used by English speakers									
1	0.00	0.05	0.00	0.10	0.00	0.05	0.10	0.00	0.05
2	0.00	0.00	0.00	0.05	0.10	0.05	0.00	0.05	0.05
3	0.00	0.00	0.05	**0.50**	**0.55**	**0.55**	0.10	0.00	0.00
4	0.00	0.00	**0.20**	Reference object			**0.31**	0.00	0.00
5	0.00	0.00	**0.15**				**0.20**	0.00	0.00
6	0.00	0.00	**0.20**				**0.15**	0.00	0.00
7	0.05	0.00	0.10	**0.15**	**0.10**	**0.20**	0.10	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

[a] Note that locations where an effect is *predicted* are indicated in bold.

terms (verbs only) appears to be roughly symmetrical across the four sides of the reference object (Table 2(a)) while English speakers' use of contact terms is asymmetrical, appearing predominantly on the upper side of the reference object (Table 2(b)).

In order to evaluate these effects, the three figure object locations contacting each side of the reference object were collapsed and compared to corresponding locations further out in each direction, designating locations adjacent to the reference object as "0", and those one or two grid spaces away from the reference object as "1" and "2", respectively (see Fig. 4 for groupings of locations). Thus, analyses were carried out as 2 (language) × 3 (distance from reference object, 0–2) × 4 (side of reference object) mixed analyses of variance, with the last two factors within-subjects.

The analysis of variance showed significant main effects of language ($F(1, 18) = 23.49$), as well as distance ($F(2, 36) = 77.81$), and side ($F(3, 54) = 4.42$) (all $P < 0.01$). Japanese speakers used more contact terms than English speakers (29 vs. 10%, respectively, across all positions), and contact terms were used only for locations adjacent to the reference object, shown by reliably greater use of contact terms in these locations than those one or two grid spaces away

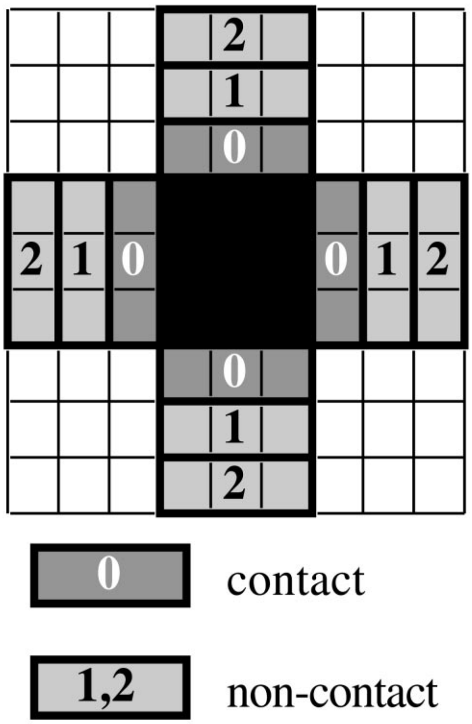

Fig. 4. Regions used in analysis of contact effects for both Language and Memory tasks in Experiment 1.

(Tukey's HSD $= 0.13$ for Japanese, 0.22 for English, $P < 0.05$; compare Table 2(a) and (b)). Like the axial terms, use of contact terms was categorical, dropping sharply in non-adjacent locations.

There were also two-way interactions of language with distance ($F(2,36) = 21.81$), language with side ($F(3,54) = 4.21$), and distance with side ($F(6,108) = 6.29$), and a three-way interaction of language, distance, and side ($F(6,108) = 3.97$) (all $P < 0.01$). Planned comparisons were carried out examining use of contact terms in adjacent vs. non-adjacent locations, for each language on each side of the reference object. Japanese speakers used contact terms significantly more often in adjacent locations than in non-adjacent locations for each side (top: $F(1,9) = 99.36$; bottom: $F(1,9) = 248.80$; left: $F(1,9) = 125.94$; right: $F(1,9) = 107.93$; all $P < 0.01$). In contrast, English speakers used terms in adjacent positions reliably more often than non-adjacent positions only on the top side ($F(1,9) = 13.05$, $P < 0.01$). The distribution of use of contact terms in adjacent positions was symmetrical around the reference object for Japanese speakers (top: 86.7%; bottom: 85%; left: 86.7%; right: 78%), but strongly biased in favor of the top side for English speakers (top: 53.3%; bottom: 15.0%; left: 18.3%; right: 20.8%). It is clear that neither group of speakers used contact terms obligatorily for the top side, a point to which we return later.

To summarize the results of the Language task, speakers of both languages showed the same strong categorical axial effects, with axial terms predominantly falling directly on the axis. Participants showed somewhat weaker effects of contact/support, and the distribution of response was somewhat different in Japanese than in English.

2.4.2. Memory task

As in the Language task, separate analyses were conducted to examine possible effects of the reference object's axial structure, and effects of contact with the reference object. In particular, we sought to determine whether the effects emerging in the Language task would also be found in this non-linguistic spatial memory task.

2.4.2.1. Axial effects. The mean proportions correct for each location are shown in Table 3(a,b). These show graded effects in accuracy, with the highest accuracy across both language groups occurring for locations on or around the reference object's axes. In order to analyze accuracy, locations were grouped into the same rows and columns as in the Language task, and analyses were carried out on the mean proportions correct, by distance from each axis, and separately for distance from the vertical vs. horizontal axes. We employed two separate 2 (language) × 5 (distance from axis, 0–4) mixed analyses of variance, each with the second factor within-subjects.

Both analyses revealed significant main effects of language (for the vertical region: $F(1,38) = 6.00$; for the horizontal region: $F(1,38) = 6.15$; both $P < 0.02$), reflecting the generally lower accuracy of Japanese speakers compared to English speakers (M percents correct 64 vs. 67%, respectively, for the vertical regions and 64 vs. 68%

Table 3
Experiment 1: proportion correct for Japanese and English speakers in the Memory task (by position of figure object)[a]

Row	Column 1	2	3	4	5	6	7	8	9
(a) Proportion correct for Japanese speakers in the Memory task									
1	0.52	0.54	0.60	0.59	**0.66**	0.59	0.58	0.52	0.51
2	0.50	0.51	0.61	0.73	**0.71**	0.69	0.57	0.58	0.55
3	0.59	0.56	**0.85**	**0.93**	**0.91**	**0.93**	**0.84**	0.62	0.55
4	0.64	0.75	**0.93**				**0.90**	0.73	0.69
5	**0.60**	**0.62**	**0.86**		Reference object		**0.84**	**0.63**	**0.60**
6	0.64	0.76	**0.92**				**0.95**	0.73	0.67
7	0.57	0.59	**0.85**	**0.89**	**0.90**	**0.93**	**0.85**	0.60	0.56
8	0.49	0.53	0.65	0.73	**0.67**	0.69	0.60	0.56	0.57
9	0.50	0.56	0.57	0.58	**0.66**	0.65	0.57	0.53	0.56
(b) Proportion correct for English speakers in the Memory task									
1	0.52	0.51	0.58	0.70	**0.77**	0.62	0.57	0.53	0.56
2	0.55	0.54	0.66	0.78	**0.80**	0.72	0.61	0.53	0.56
3	0.63	0.65	**0.89**	**0.97**	**0.93**	**0.93**	**0.89**	0.67	0.60
4	0.72	0.80	**0.95**				**0.96**	0.84	0.74
5	**0.60**	**0.71**	**0.93**		Reference object		**0.92**	**0.64**	**0.60**
6	0.72	0.83	**0.98**				**0.97**	0.83	0.74
7	0.60	0.66	**0.91**	**0.95**	**0.95**	**0.93**	**0.90**	0.69	0.59
8	0.54	0.57	0.64	0.73	**0.74**	0.73	0.66	0.57	0.53
9	0.51	0.53	0.61	0.71	**0.70**	0.63	0.57	0.53	0.53

[a] Note that locations where an effect is *predicted* are indicated in bold.

for the horizontal regions).[11] There were also main effects of distance from each axis (vertical region: $F(4, 152) = 221.08$; horizontal region: $F(4, 152) = 245.41$; both $P < 0.01$) and an interaction of language with distance from the horizontal axis ($F(4, 152) = 3.17, P < 0.02$) reflecting faster drop-off of accuracy from the horizontal axis among Japanese speakers. Planned comparisons were carried out for each language group between locations on the axis (0) and locations on the surrounding columns/rows (as in the Language task, collapsing one, two, three, or four grid spaces off-axis, i.e. columns 4 and 6, 3 and 7, 2 and 8, and 1 and 9). Accuracy was significantly higher on-axis than off-axis among both language groups, and for both axes (Vertical Axis, Japanese: $F(1, 19) = 61.80$; English: $F(1, 19) = 179.06$; Horizontal Axis, Japanese: $F(1, 19) = 25.01$; English: $F(1, 19) = 36.20$; all $P < 0.01$). This effect replicates the findings of Hayward and Tarr (1995).

However, closer inspection suggested a more complex picture than just a strict superiority for locations directly on the reference object's axes. For example, accuracy for locations directly on the vertical axis did not appear to be different from accuracy on the pair of directly adjacent columns (one off-axis, or columns 4 and 6 in Table 3(a,b)). We therefore conducted post-hoc tests between levels of distance from both the vertical and horizontal axes. Considering first the vertical axis, there were no reliable differences between accuracy on-axis and that of the directly adjacent columns (one off-axis, i.e. columns 4 and 6). However, there were reliable differences in accuracy between locations on-axis and subsequent adjacent columns (two, three, and four off-axis, i.e. columns 3 and 7, 2 and 8, and 1 and 9), with accuracy dropping in each case except the last (HSD = 0.04 for Japanese, 0.03 for English, $P < 0.05$). One possible explanation for the lack of drop between the axis and locations one off-axis is that there may have been an effect of alignment with the reference object, rendering all locations in this region equally memorable. In fact, a number of participants in the Memory task reported that they found it easier to remember the position of the figure object when it was aligned with imagined extensions of the reference object's edges.

Parallel analyses for the horizontal axis showed a similar pattern. Accuracy on the axis was reliably lower than that of rows adjacent to the axis (one off-axis, or rows 4 and 6), equal to the accuracy for locations two off-axis (rows 3 and 7), but reliably higher than accuracy for subsequent rows (three and four off-axis, or rows 2 and 8, and 1 and 9; HSD = 0.04 for both English and Japanese, $P < 0.05$). The increased accuracy in positions flanking the horizontal axis is again suggestive of an effect of alignment with the reference object's edges.

In summary, the accuracy analyses revealed clear evidence of some priority of the locations on-axis or one off-axis, compared to the surrounding locations. However, the results were not categorical as they had been in the Language task, where the locations on-axis were uniformly named by the basic spatial terms but use of these terms fell off sharply away from the axes. Accuracy in the Memory task, by contrast, revealed a more graded pattern, with possible effects of alignment with the reference object, which were not seen at all in the Language task.[12]

2.4.2.2. Contact effects. As Table 3(a,b) shows, contact between the figure and reference objects was very important to people in the Memory task: locations where the figure object was adjacent to the reference object were remembered much more accurately than those not adjacent. A 2 (language) × 3 (distance from reference object) × 4 (side of reference object) mixed analysis of variance with the last two factors within-subjects showed significant effects of language ($F(1, 38) = 6.69$, $P < 0.02$) and distance ($F(1, 38) = 984.24$, $P < 0.01$). Japanese speakers were overall less accurate than English speakers (75 vs. 80%, respectively), as in the analysis of axial positions. Post-hoc tests showed that participants were reliably more accurate for positions adjacent to the reference object than for those one grid space away, and were more accurate for these than for positions two grid

[11] Despite efforts to match language groups by level of education, English-speaking participants in the Memory task of Experiment I had a higher level of education on average than did their Japanese-speaking counterparts. For this reason, separate analyses were carried out for a subset of our participants, who were more rigorously matched for education level. These analyses revealed effects of both horizontal and vertical axes and an effect of contact, which were comparable to those found for the whole sample; however, for this matched subset, there were neither main effects of language group nor any interactions with language group.

spaces away (Tukey's HSD $= 0.02$, $P < 0.05$). There was no effect of side, nor any interactions.

This pattern suggests an effect of distance which is graded, much like the results of the Axial analyses for the Memory task. Again, these effects of contact are quite different from those in the Language task, which were categorical.

2.5. Summary of results from Experiment 1

The results showed both similarities and differences across language group and task. In the Language task, both native English and Japanese speakers showed striking categorical use of axial terms, as well as categorical use of terms expressing contact with the reference object. The axial effect for English speakers is virtually identical to that found by Hayward and Tarr (1995), and the extension to Japanese speakers suggests that the organization of these terms is quite similar in both languages. The effects for contact terms were categorical for both languages, but there were also differences in application of the terms: whereas English speakers used more contact terms on the top side of the reference object, Japanese speakers used contact terms symmetrically across all sides of the reference object.

The similarities in use of language across English and Japanese mapped clearly – but not exactly – onto patterns of performance in the Memory task: both language groups were most accurate in their memory for those locations named most consistently by the basic spatial terms, both axial and contact. However, the results for the Language task showed categorical effects whereas the results for the Memory task showed more graded effects. Moreover, differences in language use across English and Japanese did not map directly onto the patterns found in the Memory task. The only cross-linguistic difference in use of spatial terms – the distribution of contact terms around the reference object – was not reflected in analogous differences across language groups in the Memory task.

However, the lack of such an effect may have been due to the nature of the scenes we used. The scenes we used did not elicit obligatory coding of contact by native English speakers. Obligatory coding by English speakers along with non-obligatory coding by Japanese speakers are prerequisites for demonstrating any linguistically-based difference in memory. Anecdotally, many participants thought of the scenes as two-dimensional, which is incompatible with construal of support relationships. Lack of a compelling support relationship could have weakened the difference between English and Japanese speakers' linguistic coding of the scene, and thereby obscured

[12] One more analysis was conducted to examine the possibility that people's memory for location can "migrate" towards canonical spatial organizers (as found by Huttenlocher, Hedges, & Duncan, 1991; also see Rosch, 1973). If this was a factor in our experiment, and if axes were organizers in memory, then distractors moving towards the axis might produce more errors (i.e. more erroneous "same") than those which moved away from the axis. We therefore compared error rates across the two types of distractor for each language group. However, there were no systematic patterns of migration. This null result may have been due to the diagonal direction along which the distractors moved. We return to the issue of error patterns in Experiment 2.

any effects in the non-linguistic task. We examined this possibility in Experiment 2, by using scenes that much more clearly depicted support relationships. In addition, we tested the generality of the findings of Experiment 1 by extending our comparison to that between native English speakers and native speakers of Korean which, like Japanese, does not have an obligatory contrast between "on" and "above".

3. Experiment 2

Using scenes containing balls and cups resting on or hovering above a table, we tested participants' naming and memory for locations in these regions just as we had in Experiment 1. Clear portrayal of such support (and non-support) relationships should induce a sharp linguistic contrast for English speakers, but not for speakers of Korean. Such a difference between the lexicons of the two languages might be accompanied by correlated effects on memory, specifically with different memorial structures arising for speakers of the two languages in a non-linguistic task. Alternatively, speakers of the two languages might differ largely on the linguistic task alone, with memorial structures remaining constant despite years of language use.

3.1. Participants

Twenty native Korean speakers and 20 native English speakers participated, with each group roughly balanced for gender. Within each language group, no participant had been exposed to languages other than their native language before the age of 12. English participants were undergraduate students at the University of Delaware, and Korean participants were current students or graduates of universities in Korea who were studying at the University of Delaware.

3.2. Design and materials

Ten participants from each language group participated in the Language task, and the remainder participated in the Memory task. The design and tasks were identical to those in Experiment 1, with the following exceptions.

First, the stimulus scenes displayed a cup or a basketball as the figure object and a table as the reference object (see Fig. 5). Pre-testing showed that these objects elicited a strong perception of support for the appropriate locations (i.e. those in which the cup or ball were "on" the table). For each task, participants viewed a total of 25 different figure–reference object relationships, each presented with the cup and the ball, for a total of 50 scenes. The figure objects occupied one of the 25 positions in a 5×5 grid (with each grid space 0.5 inches (1.27 cm) square) which lay adjacent to the top surface of the reference object. The grid spaces were the same size as in Experiment 1, with a new column or row of squares overlapping every 0.25 inches (0.64 cm). This design was used to check whether the same distinctions would emerge in the Memory task with more fine-grained positions. In the Language task, the 50 scenes were presented once each. Participants were again asked to view each display and describe the relationship between figure and reference objects, but this time were given sentences of a slightly different form:

The cup is __________ the table.[13]

In the Memory task, each scene was presented for twelve trials (six "Same", six "Different"), for a total of 600 trials. There were also several modifications made to the distractors used in the Memory task. "Different" locations were displaced horizontally (left, right) and vertically (up only) from their initial position, rather than diagonally as in Experiment 1. This change was made so that we could more directly examine patterns of errors pertinent to possible cross-linguistic effects on memory. In particular, this made it possible to examine whether obligatory marking of contact in English would lead to sharper contact contrasts in the Memory task. Distractors were displaced by 0.125 inches (0.32 cm, as were used in Experiment 1) for half of the trials, and by 0.0625 inches (0.16 cm) for the remaining half of the trials (randomly intermixed). While performance was better overall for the larger displacements, the patterns of axial and contact effects were the same in both cases. We therefore combined data from the two levels of displacement.

Results for the Language task were coded using the same scheme as in Experiment 1. A native English speaker and a native Korean speaker coded the data in their respective languages. Twenty percent of the responses in each language group were independently coded by another native English and native Korean speaker, and the intercoder agreement scores were 99 and 97%, respectively. As was the case with Japanese speakers, Korean speakers used dictionary equivalents of the English axial terms widely, invoking these axial terms in 97% of their descriptions of axial relationships. In addition, as with Japanese speakers, these particular terms were the only means used by Korean speakers to describe axial relationships, indicating their primary status in the language. Finally, like the Japanese speakers, Korean speakers do not have an exact equivalent of "on" at their disposal, but they used equivalents of English verbs of contact and support, which are listed exhaustively in Appendix A.

3.3. Results and discussion

3.3.1. Language task

3.3.1.1. Axial effects The mean proportions of axial terms were computed as in Experiment 1 (see Fig. 6 for coding groups), and are shown in Table 4(a,b) for Korean and English, respectively. The data show a strong categorical effect of axis, as in Experiment 1, with dense use of axial terms along the axis, but not in the off-axis positions. Analyses were carried out on these data using a 2 (language) $\times$ 3 (distance from axis, 0–2) mixed analysis of variance with the second factor within-

[13] The equivalent sentence was used in the Korean version of the task: "ball-i thakca __________." (Actual stimuli were printed in Korean script.)

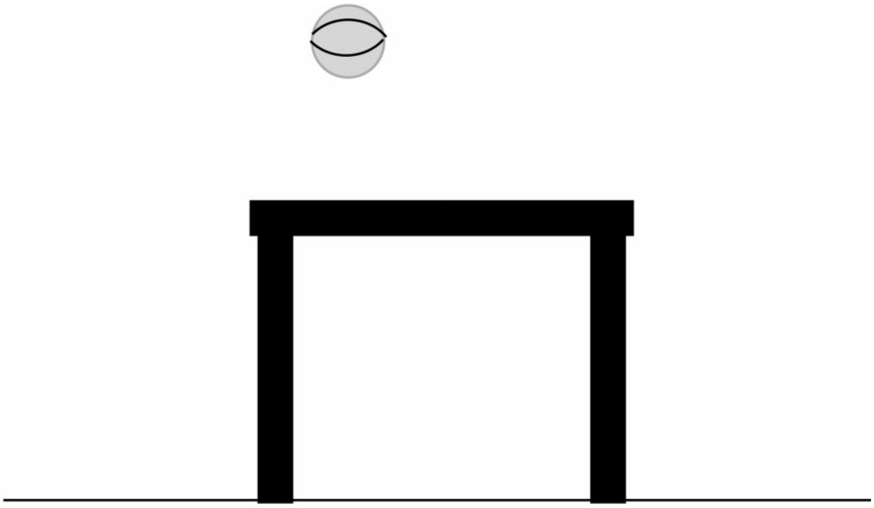

Fig. 5. Example of a display used in Experiment 2.

subjects. There was a reliable main effect of distance from axis ($F(2, 36) = 45.32$, $P < 0.01$), but no main effect of language ($F(1, 18) = 2.72$, $P > 0.05$) nor any interaction of language with distance. Locations on-axis elicited reliably more axial terms than either locations one or two grid spaces away for English and Korean separately and for the data collapsed. There were no differences between locations one and two grid spaces from the axis (Tukey's HSD = 0.18, $P < 0.05$). These effects for axial terms replicate those found in Experiment 1.

3.3.1.2. Contact effects. The mean proportions of contact terms were computed as in Experiment 1 (see Fig. 7 for coding groups), and are shown in Table 5(a,b) for Korean and English, respectively. A 2 (language) × 5 (distance from reference object, 0–4) mixed analysis of variance was carried out with the second factor within-subjects, revealing reliable main effects of language group ($F(1, 18) = 34.13$) and distance ($F(4, 72) = 111.88$) (both $P < 0.01$). English speakers used more contact terms than Korean speakers overall (20 vs. 6%). Post-hoc tests between levels of distance taken pairwise showed reliably greater use of contact terms in the adjacent locations than in any others, and no differences among the non-adjacent positions (HSD = 0.04 for English, 0.21 for Korean, $P < 0.05$).

There was also a reliable interaction between language and distance ($F(4, 72) = 35.96$, $P < 0.01$). Planned comparisons evaluating the difference between language groups in their use of contact terms showed a difference only for adjacent positions, with English speakers providing more contact terms than Korean speakers (97 vs. 27%, respectively) ($F(1, 18) = 36.09$, $P < 0.01$). In fact, the distinction was categorical among English speakers, moving from ceiling in the adjacent locations to zero in non-adjacent locations. Notably, while English speakers used contact terms uniformly in contact positions, only five Korean speakers

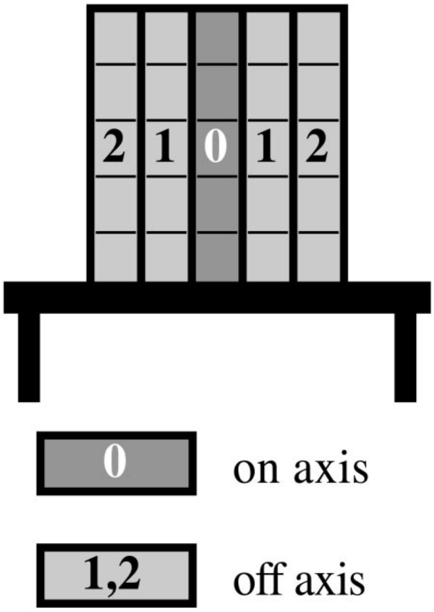

Fig. 6. Regions used in analysis of axial (vertical only) effects for both Language and Memory tasks in Experiment 2.

used them at all. Thus, the scenes of balls and cups contacting or suspended above a table appeared to elicit the obligatory "on"/"above" distinction in English, but not in Korean.

Finally, there were relatively few axial terms used by either language group in contact positions. Instead of using contact terms, English speakers often refer to contact locations as simply "on" with no axial component (e.g. simply "on", rather than "on top of"). This is consistent with the general pattern expected among English speakers of expressing support obligatorily – in this case, the importance of support apparently trumps any consideration of axial status.

3.3.2. Memory task

3.3.2.1. Axial effects The mean proportions correct by position of the figure object are shown in Table 6(a,b) for Korean and English, respectively.[14] These

[14] The overall proportion correct in the Memory task of Experiment 2 was significantly lower than that of Experiment 1 ($F(1,58) = 111.97$, $P < 0.01$). This appears to be due to differences in the distractors that we used in each experiment. In Experiment 1, the distractors were always diagonally displaced from the target, whereas in Experiment 2 they were displaced horizontally (left or right) or vertically upwards (see Section 3.2 for rationale). An inspection of the proportions correct by direction reveals that accuracy was much greater when the distractor was displaced vertically. Since we eliminated the downward distractors in Experiment 2, it is therefore not surprising that proportions correct would fall. In accord with the explanation, this drop in accuracy occurred throughout the space we sampled.

Table 4
Experiment 2: proportion of vertical terms used by Korean and English speakers[a]

Row	Column				
	1	2	3	4	5
(a) Proportion of vertical terms used by Korean speakers					
1	0.05	0.30	**0.95**	0.30	0.05
2	0.05	0.25	**1.00**	0.25	0.05
3	0.00	0.20	**0.75**	0.20	0.00
4	0.00	0.25	**0.90**	0.35	0.00
5	0.05	0.20	**0.65**	0.30	0.00
	Reference object				
(b) Proportion of vertical terms used by English speakers					
1	0.45	0.35	**0.95**	0.40	0.35
2	0.30	0.40	**1.00**	0.50	0.30
3	0.35	0.50	**0.95**	0.50	0.35
4	0.45	0.45	**1.00**	0.55	0.40
5	0.40	0.40	**0.45**	0.30	0.25
	Reference object				

[a] Data are listed by the location of the figure object relative to the reference object. The locations are laid out in a 5 × 5 grid, with the bottom side of the grid touching the reference object. Note that locations where an effect is *predicted* are indicated in bold.

data were submitted to a 2 (language) × 3 (distance from axis, 0–2) mixed analysis of variance, with the second factor within-subjects. In contrast to the Memory task in Experiment 1, there were no reliable effects of axis. However, as discussed with respect to Experiment 1, the axial effects may partly reflect enhancement of the entire region aligned with the reference object. Because we did not test locations outside of the reference object's edges, we cannot rule out this type of regional effect. The results of the Memory task also differed from those of the Language task, which showed axial effects for speakers of both languages.

3.3.2.2. Contact effects. Mean proportions correct were submitted to a 2 (language) × 5 (distance from reference object, 0–4) analysis of variance with the second factor within-subjects, revealing only an effect of distance ($F(4,72) = 33.15$, $P < 0.01$). Post-hoc comparisons revealed that location 0 (adjacent to the reference object) elicited reliably greater accuracy than any other locations; non-adjacent locations did not differ from each other (Tukey's HSD = 0.04, $P < 0.05$). Unlike the results of Experiment 1, which showed that accuracy declined in a graded fashion with increasing distance from the reference object, in this case the effect of distance appears to be entirely accounted for by the drop in accuracy between adjacent and immediately non-adjacent positions.

Further analyses were carried out to determine whether distractors that crossed a category boundary elicited higher accuracy than those that did not cross a category boundary. Specifically, we compared four cases (shown in Fig. 8). For targets that

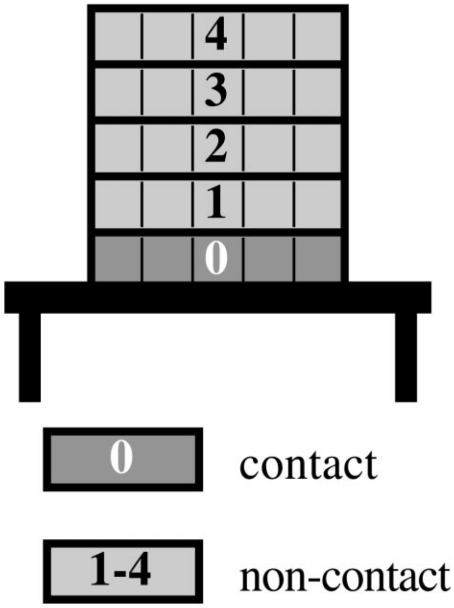

Fig. 7. Regions used in analysis of contact effects for both Language and Memory tasks in Experiment 2.

were initially in contact with the reference object, distractors could have moved (a) vertically out of contact or (b) horizontally, maintaining contact. For targets that were initially out of contact with the reference object, distractors could have moved (c) vertically, remaining out of contact or (d) horizontally, remaining out of contact. The critical question is whether there was a difference between English and Korean speakers in their memory for locations that broke the contact/non-contact boundary (distractor a), compared to distractors that did not break this boundary (b, c, or d). If there is an effect of linguistic coding on memory, then the obligatory linguistic marking of the contact/non-contact distinction by English speakers would be expected to enhance this distinction in the Memory task.

The results of a 2 (language) × 2 (initially in contact/out of contact) × 2 (vertical vs. horizontal distractor movement) mixed analysis of variance with the last two factors within-subject showed main effects of contact ($F(1, 18) = 91.46$) and direction of distractor movement ($F(1, 18) = 107$) and an interaction between the two ($F(1, 18) = 127.25$) (all $P < 0.01$). There was neither an effect of language group nor any interactions with it. Planned comparisons showed greater accuracy detecting distractors that broke the contact/non-contact boundary (i.e. the a distractors) than for each distractor type that did not break this boundary (a vs. b, a vs. c, and a vs. d; $F(1, 18) = 125.59$, 138.25, and 138.55, respectively, all $P < 0.01$).

Table 5
Experiment 2: proportion of terms indicating contact used by Korean and English speakers (by position of figure object)[a]

Row	Column				
	1	2	3	4	5
(a) Proportion of terms indicating contact used by Korean speakers					
1	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.05
5	**0.30**	**0.25**	**0.20**	**0.30**	**0.30**
	Reference object				
(b) Proportion of terms indicating contact used by English speakers					
1	0.00	0.05	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00
5	**1.00**	**1.00**	**0.90**	**0.95**	**1.00**
	Reference object				

[a] Note that locations where an effect is *predicted* are indicated in bold.

3.4. Summary of results from Experiment 2

The Language task showed strong and categorical effects of the reference object's axes among both English and Korean speakers. This replicates and extends the language findings of Experiment 1. However, unlike Experiment 1, these axial effects were not reflected at all in the results of the Memory task. The Language task also showed cross-linguistic differences in the coding of contact/support relationships: English speakers obligatorily coded the distinction between contact/support and non-contact, but Korean speakers did not. No such difference appeared in the Memory task, indicating that obligatory coding of support does not lead to better memory for contact/support positions.

4. General discussion

Across the two experiments, we found evidence for cross-linguistic similarities and differences in various aspects of spatial language. We also found similarities in spatial memory across different language groups. These similarities emerged despite the cross-linguistic differences in spatial language, suggesting that spatial memory is not affected by differences in how languages encode location. As a whole, the findings suggest that both language and memory draw on the same kinds of spatial properties, including axial structure and contact/support. However, these properties do not appear to be invoked in mandatory fashion by all languages in all memory tasks, suggesting that the relationship between the two systems is not a simple one.

Table 6
Experiment 2: proportion correct for Korean and English speakers in the Memory task (by position of figure object)[a]

Row	Column				
	1	2	3	4	5
(a) Proportion correct for Korean speakers in the Memory task					
1	0.52	0.54	0.55	0.55	0.53
2	0.54	0.56	0.57	0.53	0.53
3	0.55	0.55	0.56	0.55	0.53
4	0.55	0.55	0.57	0.56	0.57
5	**0.67**	**0.65**	**0.69**	**0.66**	**0.69**
	Reference object				
(b) Proportion correct for English speakers in the Memory task					
1	0.51	0.52	0.56	0.56	0.52
2	0.52	0.54	0.56	0.57	0.54
3	0.55	0.56	0.55	0.55	0.55
4	0.52	0.53	0.56	0.56	0.54
5	**0.66**	**0.64**	**0.71**	**0.61**	**0.66**
	Reference object				

[a] Note that locations where an effect is *predicted* are indicated in bold.

4.1. The structure of spatial language and spatial memory: similarities and differences

Two aspects of spatial language were studied – axial structure and contact/support. In both experiments, and across three languages, axial terms were used quite similarly, providing a cross-linguistic replication of the key language findings reported by Hayward and Tarr (1995). In English, Japanese, and Korean, axial terms were applied most consistently along the axes of the reference objects, and the terms were used categorically, dropping sharply outside of the region of the axis. These findings show that axial structure plays an important role in a variety of languages. Further, the fact that this structure was present in all three languages suggests the possibility that it may be an obligatory property of spatial language, encoded in all languages.

Axial structure was also reflected in the results of the Memory task of Experiment 1, suggesting that spatial memory engages some of the same spatial properties as spatial language. Axes of the reference object played a crucial role in both talking about location and remembering location. This finding is consistent with that of Hayward and Tarr, as well as numerous other findings that show a strong role for axes in tasks ranging from attentional tasks to naming tasks (Carlson-Radvansky & Irwin, 1993; Logan, 1995). However, in our results, the parallel between memory and language was far from perfect. First, whereas the effects in the Language task were categorical, those for the Memory task were graded in both English and Japanese. Second, the axial effects appeared to be modulated by a number of factors. For example, while we observed increased accuracy on the axis itself relative to

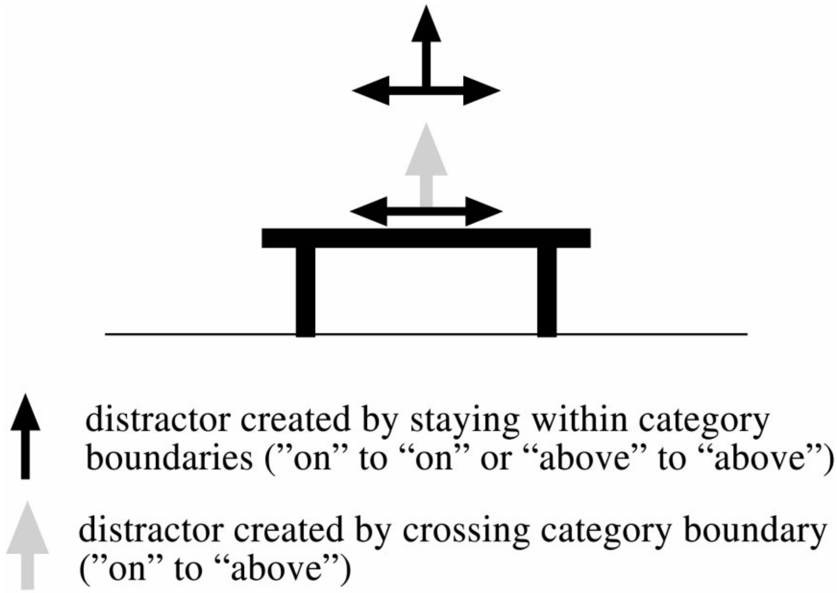

Fig. 8. Contrast used in analysis of categorical boundaries in Experiment 2. See text for further explanation.

locations in the periphery, there were also enhancing effects for locations that were off-axis but aligned with the reference objects' edges – these effects of alignment were not found by Hayward and Tarr. This difference is directly attributable to differences in the testing arrays: in Hayward and Tarr's experiments, locations directly on-axis were also aligned with the two edges of the reference object, confounding the two effects. As another example, we found no axial effects at all in the Memory task of Experiment 2. We speculate that this reflects the three-dimensional context of balls, cups, and tables, which strongly elicited the perception of support, thereby inviting people to encode location in terms of contact and support rather than the axial structure of the reference object. In short, although axial structure seems to play an important role in spatial memory and shows parallels to the structures engaged for spatial language, the underlying spatial organizations that can be used in memory tasks are clearly quite flexible, varying depending on the conceptual context and corresponding functional requirements of any given task.

Contact and support were also reflected in the Language and Memory tasks, although, as we expected, there were clear cross-linguistic differences in the obligatory linguistic use of these terms. For example, in Experiment 1, both Japanese and English speakers used contact terms largely in locations that did in fact contact the reference object. However, whereas Japanese speakers used contact terms symmetrically around the reference object, English speakers concentrated the terms more heavily on the top side than on other sides. In Experiment 2, when people's attention was focused strongly on support, English speakers obligatorily encoded contact and support using "on", and lack of contact/support using "above". In contrast, Korean speakers encoded this distinction only rarely, reflecting the fact that contact is not encoded obligatorily in their language. The Memory tasks of both experiments showed strong effects of contact in all language groups, suggesting that contact and/or support provide a strong organization for spatial memory. Thus, contact and support appear to play important roles in both systems. Yet, this spatial property appears to be optionally encoded by languages, as seen by the difference between English and Korean.

Did the cross-linguistic differences in the use of these terms affect people's performance in the Memory task? If differences in the basic distinctions of a language result in differences in non-linguistic organization, then the differences in the language of contact and support should have resulted in corresponding differences in the Memory task. However, no such effects were found. The strongest test of this possibility occurred in Experiment 2. There, English speakers categorically and obligatorily distinguished between locations in which the figure object was supported by the reference object and those in which it was located above the reference object. Korean speakers did so only sporadically. These cross-linguistic differences were not, however, mirrored by corresponding differences in the sharpness of the contact effects in the Memory task. Rather, the differences in memorial accuracy for contact vs. non-contact locations appeared consistently across the two language groups. The same pattern of results for memory was found in Experiment 1, despite cross-linguistic differences in the distribution of contact/support terms. Across the three language groups, there were equally strong effects of contact with the reference object, with contact enhancing memory for location. The lack of cross-linguistic differences in memory suggests that memory, as measured in our task, is not susceptible to long-term exposure to a particular spatial lexicon.

4.2. *Effects and non-effects of cross-linguistic difference on spatial cognition*

These findings suggest that cross-linguistic differences in spatial language need not have direct causal effects on the organization of spatial memory. How does this conclusion square with other existing findings on the language–thought relationship? First, our non-effects are consistent with the results of two recent studies by Malt, Gennari and colleagues. Malt, Sloman, Gennari, Shi, and Wang (1999) examined the domain of artifacts with Chinese, Spanish, and English speakers: participants named a variety of containers in a linguistic task, and sorted the same set of containers into categories based on perceived similarity in a non-linguistic task. Despite clear cross-linguistic differences in how the set of artifacts was carved up in naming, Malt and colleagues found no corresponding differences in how the same artifacts were carved up in the sorting task. Thus, linguistic differences did not cause changes in perceived similarity. Subsequently, Gennari, Sloman, Malt, and Fitch (2000) carried out parallel linguistic and non-linguistic tasks involving manner and path of motion in a verb-framed language (Spanish) and a satellite-framed language (English). They found the expected cross-linguistic differences in descriptions of motion scenes, but no corresponding differences in patterns of recognition memory or categorization of scenes. Again, linguistic differences could not have been the basis of patterns observed in non-linguistic tasks.

As discussed in Section 1, other investigators have reported effects of cross-linguistic differences on corresponding non-linguistic tasks. In the color domain, Davidoff et al. (1999) found that memory for color varies in accord with the distinctions made by a speaker's color lexicon, suggesting causal effects of language on cognition. Similarly, Brown and Levinson (1993) and Pederson et al. (1998) report that people can develop distinct biases for using particular reference frames in non-linguistic spatial tasks if there are correspondingly strong biases in their language (but see Li & Gleitman, 2000, for evidence that these biases can be induced in a range of circumstances **not** related to language differences).

How can we reconcile reports of both effects and non-effects of cross-linguistic differences on cognition? One possibility is that significant task differences might be responsible for these discrepancies in outcome. For example, the experiments of Brown and Levinson, Pederson et al., and Davidoff et al. all used non-linguistic tasks that allowed participants ample time to encode the stimuli, which could have invited verbal encoding even in the absence of verbal responses. If people did verbally encode location, this would naturally have led to results consistent with the preferred linguistic categorizations. In contrast to these studies, our Memory task required people to spatially encode objects' locations under very short exposure durations, which made verbal encoding highly unlikely. Furthermore, our stimuli were followed by visual masks and were displaced by a small amount in order to prevent visual persistence. The spatial distinctions (between Same and Different locations) were quite fine-grained, and thus ill-suited to making verbal distinctions. Finally, the memory structures that were revealed in our data were not isomorphic to those elicited in the Language task, indicating that they were not in fact mediated by verbal encoding. These memory structures are clearly mental representations – they were not precise at every distance from the reference object, but rather, reflected mental organization in terms of the reference object's axes and support relationships. Cross-linguistic differences appear not to have effects on these non-linguistic spatial representations, suggesting a lower boundary on the locus of cross-linguistic effects.

A second possibility is that the particular spatial representations we investigated are basic enough that they resist effects of language variation. Imai and Gentner (1997) have recently suggested that effects of language on non-linguistic categorization may only take place in the absence of strong universal tendencies. They offer this argument as a way of understanding the simultaneous presence of positive and negative effects of cross-linguistic differences on object categorization. Specifically, Lucy (1992) and Imai and Gentner (1997) examined patterns of generalization in object sorting tasks among English speakers vs. Yucatec-Mayan and Japanese speakers. When given a sample object, and asked to categorize other objects on the basis of their similarity to the sample, English speakers tended to generalize on the basis of object shape, whereas Yucatec-Mayan and Japanese speakers sometimes generalized on the basis of material. Both Lucy and Imai and Gentner attributed these different patterns of non-linguistic sorting to a syntactic difference between English and the other two languages, and in particular the obligatory English marking of the distinction between objects and substances, which is not made in either Yucatec-Mayan or Japanese.[15] In contrast, Imai and Gentner found that **both** Japanese and English speakers tended to generalize on the basis of shape when grouping "complex" objects, i.e. rigid objects with complex shapes that are typical of most artifacts. It was only for "simple" objects – simple geometric shapes with few parts – that the cross-linguistic difference emerged. This led them to propose the presence of a universal bias towards grouping artifactual concrete objects by shape – one which would have dominated any cross-linguistic effects and resulted in shape-based judgments for "complex" (artifact-like) objects among both English and Japanese speakers (see also Yoshida & Smith, 1999).

Both axial structure and contact/support are properties of spatial organization that are likely to be foundational to both language and cognition. If these structures constitute strong universals in spatial cognition, then linguistic variation on this basic pattern might tend not to have any effects on non-linguistic spatial organization. Similarly, perceptual similarity of containers, as well as manner and path of motion events, as examined by Malt, Gennari, and colleagues, may also constitute such strong universals. Just as the perception of complex object shape might preempt any effects of cross-linguistic variation, these arguably universal dimensions of spatial cognition might preempt such effects as well.

To conclude, our evidence reveals that spatial language and spatial memory engage similar spatial properties – axial structure and contact/support. At the same time, where we did find clear cross-linguistic differences, there was no evidence of corresponding differences in the non-linguistic organization of space. This indicates that, to the extent that there are similarities between spatial language and non-linguistic spatial cognition, linguistic representations do not play a major role in shaping non-linguistic representations. Finally, although similar properties were reflected in both the Language and Memory tasks, these properties were not mandatory across the Language or Memory tasks. Although axial structure emerged in both language and memory in the first experiment, it did not emerge across both tasks in the second experiment. Similarly, although contact and support emerged in both Memory tasks, it did not appear across speaker groups in the two Language

[15] The complementary distribution of unitizers and pluralizers in English corresponds to the distinction between count and mass nouns. Specifically, English requires use of the plural form to characterize several animate entities or discrete objects (e.g. "two turkeys", "two bananas"), but does not directly pluralize nouns referring to materials (e.g. *"two cottons", *"two zincs"); instead, in order to quantify materials English requires a "unitizer" such as "basket" or "jar" which takes on the plural form (e.g. "basket*s* of cotton", "jar*s* of zinc") Yucatec-Mayan, on the other hand, uses unitizers for both objects and materials, as in the following:

ka′a tuul uulum

(two)(unitizer) (turkey)

"two turkeys"

(All examples borrowed from Lucy, 1992; note that the convention of denoting ungrammatical expressions with an asterisk has been adopted here.)

tasks. This lack of a perfect correspondence between language and memory suggests that the two systems draw somewhat independently on the same set of properties (see Crawford et al., 2000, for more direct evidence in this direction). Although there may be a universal base of properties for linguistic and non-linguistic tasks, a perfect isomorphism clearly does not exist between the two systems.

How and why might language and memory have emerged to represent the same sets of spatial properties? One possibility is that these similarities evolved by building language "on top of" non-linguistic spatial representations. In this view, evolutionary pressures inherent in the non-linguistic spatial domain might become internalized as part of our representational systems (Shepard, 1984), and these might then give rise to similarities in the structures of the language of space (see, for example, Landau & Jackendoff, 1993; Pinker & Bloom, 1990). Another possibility is that functional considerations pertaining to the task of locating objects – either linguistic or non-linguistic – naturally give rise to the need for the same class of distinctions; this could then lead to parallel emergence of systems that preserve the same kinds of spatial distinctions (Freyd, 1983; Landau & Jackendoff, 1993). Whether searching for an object, picking it up, or talking about its location, certain structures – such as reference systems – and certain properties – such as contact and support – are likely to be important. From this observation, it might come as no surprise that the same properties are preserved by the two systems: the task of negotiating space is, after all, constrained by the physical space we live in, our perceptual capacities to detect spatial information, and common evolutionary demands.

Acknowledgements

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Appendix A. Expressions used in language tasks of Experiments 1 and 2

English	*Japanese*	*Korean*
AXIAL TERMS		
above, over	ue (-ni), jouhou (-ni)	wi (-e)
below, under	shita (-ni), kahou (-ni)	–
(to the) left	hidari (-ni)	oencho (-e)
(to the) right	migi (-ni)	oreuncho (-e)
next (to)	tonari (-ni)	

(*continued*)

English	*Japanese*	*Korean*
above (and to the) left	ue (-ni), hidari (-ni)	wi (-e), oencho (-e)
below (and to the) right	shita (-ni) migi (-ni)	– oreuncho (-e)
(to the) left (and) above	hidari (-ni), ue (-ni)	oencho (-e), wi (-e)
(to the) right (and) below	migi (-ni) shita (-ni)	oreuncho (-e) –
(to the) top left	–	–
(to the) top right	–	–
(to the) bottom left	–	–
(to the) bottom right	–	–
(to the) left top	hidari ue (-ni)	oenchok wi (-e)
(to the) left bottom	hidari shita (-ni)	–
(to the) right top	migi ue (-ni)	oreunchok
(to the) right bottom	migi shita (-ni)	–
CONTACT TERMS		
[being] on	notte	noye
sitting	tsuite	–
touching	sesshite	–
[sticking to]	kuttsuite	putte
TERMS DENOTING LACK OF CONTACT		
hovering	–	–
floating	uite	tte
away from	hanarete	–

Note: square brackets denote English translations of expressions used by Japanese- or Korean-speaking participants, but which English speakers never used; parentheses denote the functional morphemes that typically accompanied the lexical morphemes with which we were concerned.

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