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The Influence of Movement, Alignment and Orientation on the Comprehension of Spatial Adpositions in English and Finnish

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In contrast to English, Finnish has several postpositions which indicate *in front of* locations (*edellä*, *edessä*) and *behind* locations (*takana, jäljessä* and *perässä*). Based on predictions generated from findings from other prepositions in English, and following the prediction by Nikanne (2003) that some postpositions mark motion while others do not, an experiment was designed to examine the influence of movement, alignment, and orientation of located and reference objects on the comprehension of *in front of* and *behind* in English and the corresponding Finnish post-positions. Native speakers of English and Finnish had to rate the appropriateness of sentences containing these terms to describe pictures of cars at various positions on a roundabout. The results show similarity between "in front of" and "behind" terms across languages. While movement does distinguish between "behind" terms in Finnish, in both Finnish and English movement only affected the acceptability of "in front of" and "behind" when reference frame conflicts were present.

Keywords: Spatial prepositions and post-positions, geometry, movement.

Spatial adpositions comprise an essential part of the lexicon for a speaker to acquire. Such terms have the function of indicating where one object is located with reference to another object(s). However, the effective comprehension and production of spatial prepositions in English involves not only knowledge of "where" objects are located, but also of "what" those objects are and "how" they

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interact (or may interact) with each other. For example, Coventry, Prat-Sala and Richards (2001) found that whether an object was shown to be fulfilling its protecting function (e.g., whether rain was shown to fall on an umbrella or on the man the umbrella was supposed to protect) influenced acceptability ratings for the prepositions *over*, *under*, *above* and *below* in order to describe the relative positions of the umbrella and man. Actual or potential movement between objects have also been found to influence the comprehension and production of a range of spatial prepositions in English including *in, on*, *over*, *under*, *above* and *below* (e.g., Carlson-Radvansky, Covey & Lattanzi, 1999; Garrod, Ferrier & Campbell, 1999; Richards, Coventry & Clibbens, 2004; see Coventry & Garrod, 2004 for a review).

Although the influence of how objects interact or may interact with each other has been shown for the comprehension of several spatial prepositions in English, thus far the prepositions *in front of* and *behind* have received little empirical attention. Additionally, although the importance of extra-geometric relations has been recognised in relation to cross-linguistic work (Coventry & Guijarro-Fuentes, 2004; Vandeloise, 1991, 1994), it has yet to be established empirically whether these effects occur across a wider range of languages. Indeed, there is much debate about whether the same underlying non-linguistic spatial parameters underlie all languages (e.g., see for example Landau & Jackendoff, 1993; Mandler, 1996), or whether there are language-specific constraints which allow the development of spatial concepts for language (Bowerman, 1996a and b; Choi & Bowerman, 1991; McDonough, Choi & Mandler, 2003).

Recently Coventry and Garrod (2004) have suggested that differences between languages in the way they carve up space may be better understood by considering both geometric and extra-geometric constraints. They distinguish between what they call "geometric routines" and two sources of extra-geometric constraints; "dynamic-kinematic routines" and "object knowledge". An example of a geometric routine is the attention vector sum model proposed by Regier and Carlson (2001) which computes geometric relations between a located object and a reference object in the scene being described mediated by an attentional mechanism. Dynamic-kinematic routines involve the computation of potential or actual movement between objects (e.g, Coventry, Prat-Sala & Richards, 2001). For example, Garrod, Ferrier and Campbell (1999) found that acceptability ratings for *in* to describe the position of an object relative to a container correlated with judgements of the likelihood that the object and container would remain in the same relative positions over time should the container be moved (see also Coventry, 1998; Richards, Coventry & Clibbens, 2004). These parameters are linked to knowledge of objects in the scene being described. For example, while a plate can contain a small object such that the object can be geometrically within the convex hull region of the plate, it is primarily conceptualised as a supporting surface, and consequently the presence or absence of a support relation is the relevant spatial relation for that object (Coventry, Carmichael & Garrod, 1994; Coventry & Prat-Sala, 2001). Similarly, the application of geometric and dynamic-kinematic routines is also weighted by preposition. For example, in English acceptability ratings for *above* and *below* are more affected by geometry than those for *over* and *under* while conversely acceptability ratings for *over* and *under* are more influenced by dynamic-kinematic routines than those for *above* and *below* (Coventry et al., 2001). It is the interplay between these constraints which Coventry and Garrod (2004) argue provides an understanding of the comprehension of spatial prepositions in English, and by extension, to other languages. We first consider how these factors might affect the comprehension of *in front of* and *behind* in English before considering how "in front of" and "behind" terms operate differently (according to Nikanne, 2003) in Finnish.

In Front of and Behind in English

Given the effects of both geometric and extra-geometric factors on the comprehension of a range of prepositions in English, one might expect that such factors also play a role in the comprehension of *in front of* and *behind*. In relation to geometry, the importance of alignment and distance between objects have been established for terms such as *above* (Logan & Sadler, 1996; Hayward & Tarr, 1995; Regier & Carlson, 2001). Similarly for *in front of*, children and adults show a preference when placing an object *in front of* another object for placing the object directly in line with the intrinsic front of the reference object (e.g., Abkarian, 1982; Harris & Strommen, 1972; Kuczaj & Maratsos, 1975; Landau, 1996). For example, Landau (1996) presented children (three-year olds and five-year olds) and adults with three reference objects, and they were asked either to place an object *in front of* or *behind* each reference object, or to judge which locations were acceptable for these terms. The reference objects were a flat disc, a U-shaped object and a flat disc-shaped object with eyes and a tail. When the reference object has an intrinsic front (i.e., the disc-shaped objects with eyes) adults place the located object directly "in front of" or "behind" the half axes extending out from the eyes (for *in front of*) or tail (for *behind*) of the reference object (i.e., along the intrinsic axis). Regions extending outwards from the half axes beyond the left-most or right-most parts of the reference object (i.e., outside the "bounding box" of the reference object) were also appropriate for adults (though less so than points within the bounding box). The extension of acceptability away from the axes was not observed as strongly for the reference objects without clear intrinsic fronts. These results mirror the gradedness in responses found by Logan and Sadler (1996), among others, for terms such as *above* and *below*, and show that assigning a reference frame is important for these terms.

In front of and *behind* are ambiguous with respect to reference frame assignment. Following Levinson (1996), one can distinguish between the intrinsic (object-centred), relative (viewer-centred) and absolute reference frames. The intrinsic and relative reference frames are particularly relevant for *in front of* and *behind*. For example, *The cat is in front of the chair* used

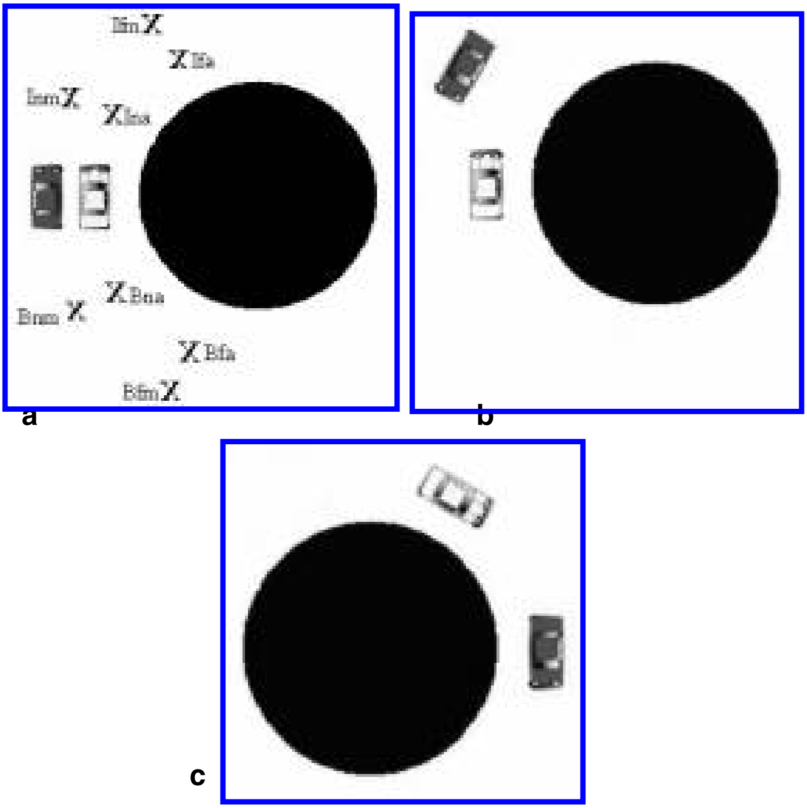

Figure 1. Examples of scenes used: (a) Schematic representation of scene and positions used (B = behind positions, I = in front of positions, f = far, n = near, a = aligned, m = misaligned). (b) An example of a static scene where the located and reference objects are misaligned, facing each other and are near each other. (c) An example of a static scene where the located and reference objects are aligned, facing the same way and are far apart. Note that the pictures are black and white representations of the colored scenes used.

intrinsically locates the cat in front of the intrinsic front of the chair (which is the part of the chair we interact with). In contrast, if the speaker and hearer were standing to the side of the chair, *in front of the chair* using the relative reference frame (with reference to the positions of the speaker and hearer) would locate the cat at the opposite side of the chair to the side they are standing (although this is not the case for all languages; see Hill, 1982; Levinson, 2003 for discussion).

Just as the ascription of front and back to objects affects the regions of acceptability for *in front of* and *behind*, it is also the case that the orientation of the located object is also important. For example, two people facing each other can be described as being *in front of* each other (in English, though not in all languages; Levinson, 1996), but two people facing the same way cannot be described as being *in front of* each other in English (Levelt, 1984; Levinson, 1996). Indeed, Carlson-Radvansky and Radvansky (1996) found that participants were more likely to say that *The mail carrier is in front of the mail box* when the mail carrier and mailbox were facing each other than when they were facing away from each other (when expressions such as *The mail carrier is to the left of the mail box* were preferred). In addition, Jackendoff (1996) has argued that motion is one way in which an intrinsic reference frame can be established. The front of a billiard ball in motion is the side that is always ahead in the path of motion. Therefore, it may be predicted that, although the distance between located object and reference object maybe constant, depiction of motion may affect the appropriateness of *in front of* and *behind* to describe scenes.

Consider the scenario of cars positioned on a roundabout with two lanes (see Figure 1). With the scenario comes an assumption that cars will move in a particular direction round the roundabout. However, there may also be the expectation that objects will move in the direction of their intrinsic fronts. Therefore, if two cars are facing each other, there may be competition between the intrinsic frame and the motion frame supplied by knowledge of the direction in which the objects should move. Displaying the objects in motion gives clear indication of the frame that is specified, so competition from the intrinsic frame may be reduced. Furthermore, if dynamic-kinematic routines are important for *in front of* and *behind*, we might expect motion to influence the acceptability of *in front of* and *behind* in another way. When cars are both facing in the direction of expected motion, if they are actually moving at the same rate *in front of* and *behind* may be more appropriate than if the cars are stationary, as the cars when they are stationary have the potential to change speeds and directions. Additionally, by extension from previous work with other prepositions, it is likely to be the case that there are interactions between orientation, geometry and movement for *in front of* and *behind* also. For instance, by extension from work on *in* (Coventry, 1998; Garrod et al., 1999; Richards et al., 2004[1]) we

[1]Moving the located and reference objects together (demonstrating "location control" of the located object by the reference object; the dynamic-kinematic routine for *in*) only affects the comprehension and production of *in* for containment scenes when the containment relation is weak. For example, imagine a pear in a container. When the pear is contained within the space the container occupies (i.e., below the rim), moving the container and pear together such that they remain in the same relative positions over time does not affect the acceptability of *the pear is in the bowl* (compared with a no movement static scene). However, when the pear is piled on top of other fruit in the bowl (i.e., above the rim), demonstrating location control does increase the acceptability of *The pear is in the bowl* to describe the scene.

expected that the effects of movement may only occur when the geometry is weak for *in front of* and *behind* (i.e., when the cars in the roundabout are in different lanes rather than in the same lane).

Differences Between Finnish and English

In contrast to English, Finnish has a particularly rich and varied means of expressing location. Most of the adpositions (prepositions and postpositions in Finnish) are cases of nouns, (see Penttilä, 1957 for a comprehensive list and Nikanne, 1993 for a classification of adpositions in Finnish), and they can be divided into those that are phonologically empty and those that are overt (Nikanne, 1993). Included in the former category are the locative cases, which can be combined with postpositions. As part of the rich postpositional system, Finnish has several lexical items, *edessä/edellä*, and *takana/perässä/jäljessä* which map onto *in front of* and *behind* in English (in addition to other ways of expressing these relations). Nikanne (2003) has suggested that the increased number of lexical items in Finnish is associated with a finer discrimination of spatial organisation. Specifically, Nikanne suggests that while *perässä* and *jäljessä (behind)* and *edellä* (in front of) indicate mutual horizontal movement, *takana* (*in front of*) and *edessä* (*behind*) are acceptable when describing either moving or static objects. In contrast, Nikanne assumes that movement does not affect the comprehension of *in front of* and *behind* in English.

The aim of the experiment we report below was to establish whether motion, relative position (manipulated in terms of alignment and proximity) and orientation influence the comprehension of "in front of" and "behind" terms in English and Finnish, and whether these factors interact (as we predict) or operate independently. Specifically, we wanted to test whether motion influences the acceptability of these terms in the same way as has been found for a range of other prepositions (dynamic-kinematic routines), and/or whether motion affects the acceptability of these terms by means of reducing reference frame ambiguity. In addition, we wanted to test Nikanne's claim that some postpositions in Finnish are marked for motion while others are not. For that reason the present study was designed to examine the relative influences of these variables on (i) *in front of* and (ii) *behind* in English and their Finnish postposition equivalents (i) *edessä* and *edellä*, and (ii) *takana*, *perässä* and *jäljessä*. Consider again the roundabout scenario. Following Nikanne (2003) it can be predicted that the effects of relative motion, where cars on the roundabout are shown in motion moving round the roundabout at a constant speed (with the same distance between cars at all times), should not affect the comprehension of *in front of* and *behind* in English or *edessä* and *jäljessä* in Finnish but should affect the comprehension of *edellä*, *takana*, and *perässä* in Finnish. In contrast, we predicted, in line with work on other prepositions (Coventry and Garrod, 2004) that relative motion should affect the comprehension of *in front of* and *behind* in English. For both languages, we also expected that the influence of motion may be affected by the orientation of the cars involved, and whether the cars are aligned or not (by extension from work from other prepositions).

Design and Participants

Thirty-one monolingual English speakers and thirty-one monolingual Finnish speakers participated in the study. All were undergraduate students in England and Finland respectively. Participants were presented with a computer-generated rating task where they had to rate the appropriateness of sentences containing pre- or post-positions (using a scale from 1-7 where 1 = unacceptable and 7 = good, with 4 = neither unacceptable nor acceptable) in order to describe pictures of cars positioned around a roundabout. Participants were instructed at the outset that traffic on the roundabout moves in a clockwise direction (thus licensing the use of the accidental intrinsic frame within a viewer-centred reference frame). The sentences presented were always of the form *the coloured car is adposition the white car* for English (and *värillinen auto on valkoisen auton adposition* for Finnish). Scenes always contained two cars, and the relative positions of the cars were manipulated in several ways (see Figure 1 for a schematic diagram showing layout together with specific examples of scenes). The cars were either in the same (aligned—e.g., Figure 1c) or different (misaligned—e.g., Figure 1b) lanes on the roundabout. The located car was also either positioned "near" (as in Figure 1b) or "far" (as in Figure 1c) from the reference car either "in front" or "behind" the reference car. Finally, the orientation of the located car was manipulated such that it either faced towards (as in Figure 1b) or away (as in Figure 1c) from the reference car. Intrinsic fronts of cars were clearly indicated by marking of the steering wheel in each car. At the beginning of the experiment, the experimenter checked that participants could readily identify the fronts of the vehicles, and were aware that there were two lanes in the roundabout (an inside and an outside lane). All participants were able to identify fronts easily and quickly, and were clear that there were two lanes in the roundabout (even though these were not explicitly marked). The white car was always the reference object and always faced in the direction of expected motion (i.e., driving the correct way round the roundabout), while the position of the coloured car was manipulated.

In addition to relative position, the scenes involved either movement or no movement in order to test the claim that Finnish adpositions allow finer discrimination than English. For moving scenes, the cars were viewed driving round the roundabout (clockwise) at a constant speed remaining the same distance apart at all times. The 2 (movement) × 2 (alignment) × 2 (in front of versus behind positions) × 2 (orientation) × 2 (proximity) design produced 32 scenes covering all possible combinations of these variables.

Materials and Procedure

The task was programmed in Visual Basic and presented on a laptop computer. In addition to the manipulations an extra position (misaligned and next to the reference object, as shown in Figure 1a) was included to cover all positions on a grid (adding 8 extra scenes), and 16 distractor scenes were also added which depicted erratic (random) movement between located and reference object for every cell of the design. These scenes were included to distract participants from falling into a pattern of responding just based on movement versus no movement. The resulting 56 scenes were presented in random order. For each scene the participants were given a set of adpositions to rate for appropriateness presented on the screen immediately below the visual scene. In addition to *in front of* and *behind* terms, for both Finnish and English, *near* and *far* (*lähellä* and *kaukana* prepositions in Finnish) were also included. Sentences were presented one-by-one and the order of sentences was fully randomised in order to avoid priming effects from one adposition to another. For moving scenes, movement continued throughout the presentation of all the sentences. Also, in order to make the tasks in English and Finnish equivalent (given the greater numbers of adpositions in Finnish), three sentences were added to the English task which instructed them to click on any number to continue in order to even up the time taken for each task.

Results

Given that there are different numbers of lexical items to express "in front of" and "behind" relations in Finnish and English, the data for each language were analysed individually using separate analyses of variance for the "in front of" terms in the "in front of" positions, and the "behind" terms in the "behind" positions. Where follow-up analyses were required, Newman-Keuls tests were used. For each analysis the variables were alignment (misaligned or aligned), movement (located and reference objects moving together or static), orientation (normal or reversed), and postposition (for Finnish only). To simplify the analyses, we collapsed across proximity, and therefore did not include it as a separate variable in the analyses.

"In Front of" Term(s)

English: In Front of

The mean ratings and standard deviations are displayed in Table 1. The data were analysed using a three-way within subjects analysis of variance. The variables were alignment (located and reference objects aligned or misaligned), movement (located and reference objects moving together or static) and orientation (cars facing same way or facing each other).

There were significant main effects of both alignment, $F(1, 30) = 11.45$, $p < .01$, $MSE = 0.56$, and orientation, $F(1, 30) = 4.28$, $p < .05$, $MSE = 1.15$.

Table 1
Mean Ratings (and Standard Deviations) for In Front of *in English*

	Misaligned	Aligned
Cars moving together		
Facing same way	5.55 (1.70)	6.76 (0.60)
Facing each other	6.45 (1.17)	6.39 (1.33)
No movement		
Facing same way	6.68 (0.95)	6.78 (0.80)
Facing each other	5.87 (1.73)	5.92 (1.85)

Higher ratings were given for aligned (M = 6.46) than for misaligned positions (M = 6.14), and for same orientation (cars facing same way, M = 6.44) than for different orientations (cars facing towards each other, M = 6.16). There was also a significant interaction between orientation and alignment, $F(1, 30) = 10.75$, $p < .01$, $MSE = 0.63$. An effect of alignment was found only when the cars were facing the same way (M = 6.77 for cars aligned and M = 6.11 for cars misaligned) but not when the cars were facing each other (M = 6.16 for cars aligned, M = 6.15 for cars misaligned). In other words, when the intrinsic frames of the cars do not match, alignment does not affect ratings given by participants.

Of most interest were the interactions involving movement. First, there was a significant interaction between movement and alignment, $F(1, 30) = 5.65$, $p < .05$, $MSE = 0.69$. Movement increased acceptability when the cars were aligned (M = 6.57 for moving scenes and M = 6.35 for static scenes) while movement decreased acceptability when the cars were misaligned (M = 6.00 for moving scenes and M = 6.27 for static scenes).

There was also a significant interaction between orientation and movement, $F(1, 30) = 15.74$, $p < .001$, $MSE = 1.18$. When the cars were facing the same way ratings for static scenes (M = 6.73) were higher than ratings for moving scenes (M = 6.15). When the cars were facing each other moving scenes were given higher ratings (M = 6.42) than static scenes (M = 5.90).

Finally, there was a significant three-way interaction between movement, orientation and alignment, $F(1, 30) = 6.85$, $p < .05$, $MSE = 0.85$. This interaction is displayed in Figure 2. When the located object is facing in the same direction as the reference object, there is a large effect of movement when the objects are misaligned ($p < .001$), but no effect when the objects are aligned ($p > .05$). Notably, this effect of movement was in the opposite direction to that predicted; ratings were higher for static scenes than for movement scenes. However, when the located object and the reference object are facing each other the pattern is rather different. The ratings for movement scenes were higher than for static scenes at all levels of alignment, although the only significant effect of movement was when the cars were misaligned ($p < .05$).

The results for movement indicate that when the cars are facing each other, movement increases the acceptability of *in front of* irrespective of the alignment of the cars. Under such circumstances it is likely that motion instantiates the

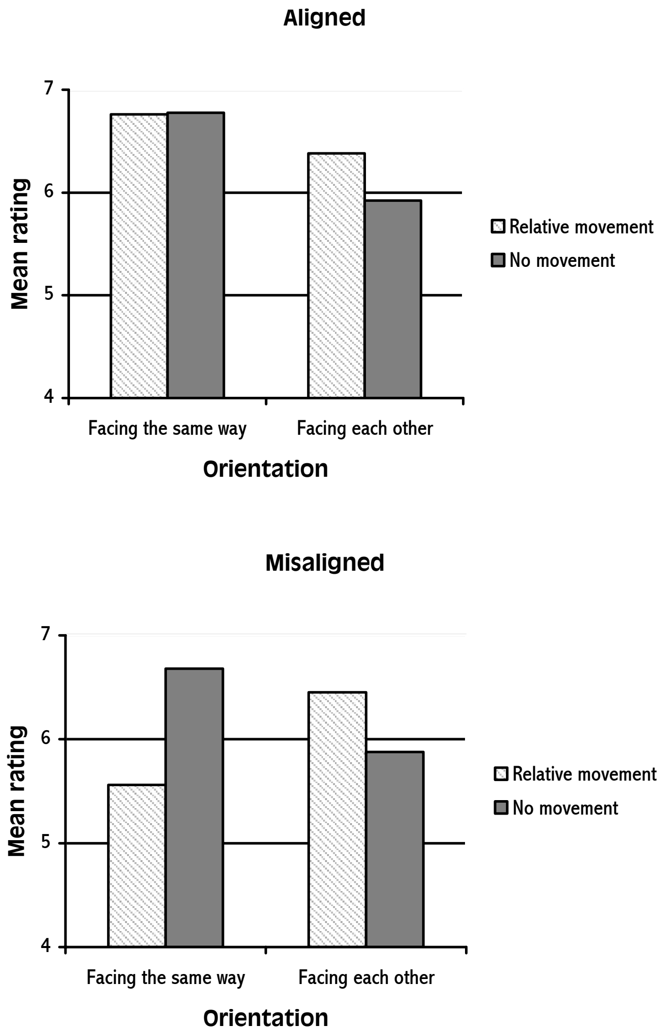

Figure 2. Three-way interaction (Alignment × Movement × Orientation) for *in front of* in English.

accidental intrinsic frame, and therefore overrides potential conflicts between the intrinsic axes of the located and reference objects vis-à-vis the intrinsic frame. However, when the cars are facing in the same direction, movement actually decreases the acceptability of *in front of*, but only when the located object is positioned non-prototypically (outside the bounding box of the

Table 2
Mean Ratings (and Standard Deviations) for Edellä *and* Edessä *in Finnish*

	Edellä		Edessä	
	Misaligned	Aligned	Misaligned	Aligned
Cars Moving Together				
Facing same way	6.11 (1.62)	6.91 (0.54)	5.67 (1.96)	6.66 (1.30)
Facing each other	6.76 (0.89)	6.84 (0.55)	6.45 (0.97)	6.83 (0.68)
No Movement				
Facing same way	6.76 (0.79)	6.73 (0.98)	6.37 (1.08)	6.68 (1.07)
Facing each other	6.16 (1.72)	6.32 (1.64)	6.28 (1.39)	6.57 (1.41)

reference object). For such scenes motion may draw attention to the fact that the cars are continuously misaligned, leading to a reduction in acceptability rating. So movement does affect comprehension of *in front of*, as predicted when cars are facing each other, but not as predicted when they are facing in the same direction.

Finnish: Edellä and Edessä

The mean ratings and standard deviations are shown in Table 2. The data were analysed using a four-way within subjects analysis of variance. The variables were alignment (located and reference objects aligned or misaligned), movement (located and reference objects moving together or static), orientation (cars facing same way or facing each other) and post-position (*edellä* or *edessä*).

A significant main effect of alignment was found, $F(1, 30) = 14.91$, $p < .0001$, $MSE = 1.12$, consistent with that found for *in front of* in English. There was also a two-way interaction between orientation and alignment, $F(1, 30) = 4.28$, $p < 0.05$, $MSE = 0.58$. An effect of alignment was found when the cars were facing the same way (M = 6.75 for cars aligned and $M = 6.23$ for cars misaligned), but not when the cars were facing each other ($M = 6.64$ for cars aligned and $M = 6.41$ for cars misaligned), again consistent with the results for English.

Of most interest are the patterns of interactions involving movement and/or post-positions. There was a two-way interaction between movement and alignment, $F(1, 30) = 4.60$, $p < .05$, $MSE = 0.93$. There was an effect of movement when the cars were aligned ($M = 6.81$ for moving scenes, $M = 6.57$ for static scenes), but when the cars were misaligned the effect was in the opposite direction ($M = 6.25$ for moving scenes, $M = 6.39$ for static scenes). There was also an interaction between movement and orientation, $\underline{F}(1, 30) = 9.83$, $p < .01$, $MSE = 1.45$. When cars were facing the same way ratings were higher for static ($M = 6.63$) than for moving ($M = 6.34$) scenes, but when the cars were facing each other ratings for moving scenes were higher ($M = 6.72$) than for static scenes ($M = 6.33$). These results are again consistent with those for *in front of* in English. Movement affects acceptability rating in the predicted

Table 3
Mean Ratings (and Standard Deviations) for Behind *in English*

	Misaligned	Aligned
Cars Moving Together		
Facing same way	6.60 (0.96)	6.41 (1.23)
Facing each other	6.28 (1.31)	6.52 (0.94)
No Movement		
Facing same way	6.47 (1.25)	6.36 (1.58)
Facing each other	5.58 (1.94)	5.76 (1.71)

direction only when the cars are facing each other. Hence movement provides information that the accidental intrinsic frame is instantiated.

There was only one significant effect involving post-position, which was a significant two-way interaction between orientation and post-position, $F(1, 30) = 5.62$, $p < .05$, $MSE = 0.44$. When cars are facing each other, ratings for *edellä* and *edessä* are very similar ($M = 6.52$ for *edellä* and $M = 6.53$ for *edessä*), but when cars are facing in the same direction ratings for *edellä* are higher (M = 6.63) than ratings for *edessä* ($M = 6.35$). The absence of an interaction between post-position and movement is not consistent with Nikanne's (2003) predictions. It would appear that *edellä* and *edessä* are not differentiated in terms of movement.

None of the other main effects or interactions were significant.

"Behind" Term(s)

English: Behind

The mean ratings and standard deviations are displayed in Table 3. The data were analysed using a three-way within subjects analysis of variance. The variables were alignment (located and reference objects aligned or misaligned), movement (located and reference objects moving together or static) and orientation (cars facing same way or facing each other). Significant main effects of movement, $F = 9.31$, $MSE = 2.21$, $p < .01$, and orientation, $F = 10.41$, $MSE = 2.14$, $p < .01$, were found. Ratings were higher for moving ($M = 6.45$) than for static scenes ($M = 6.04$), and for the scenes where the cars faced the same way ($M = 6.46$) as compared with scenes where the cars faced each ($M = 6.03$).

A significant two-way interaction between movement and orientation was found, $F = 6.37$, $MSE = 1.97$, $p < .05$ (displayed in Figure 3). When the cars were facing the same way, the movement condition ($M = 6.50$) received only slightly higher ratings than the static ($M = 6.41$) condition. Whereas, in the reversed condition relative movement ($M = 6.39$) was rated significantly higher than the static ($M = 5.67$) condition ($p < .001$). This result is consistent with the results found for *in front of*. The effect of movement is only present when there is ambiguity about the reference frame present in the scene. Movement under

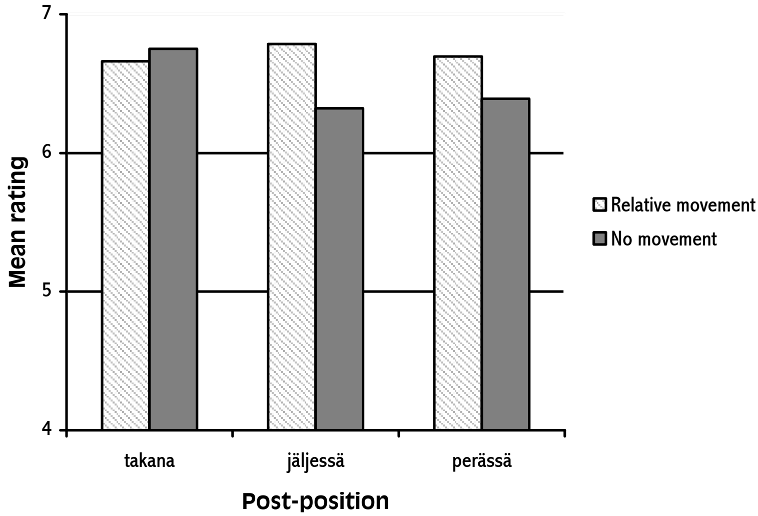

Figure 3. Interaction between movement and post-position for *behind* terms in Finnish.

these circumstances gives indication that the accidental intrinsic frame is the relevant frame within which to interpret the term. None of the other main effects or interactions were significant.

Finnish: Takana, Jäljessä and Perässä

The mean ratings and standard deviations are shown in Table 4. The data were analysed using a four-way within subjects analysis of variance. The variables were alignment (located and reference objects aligned or misaligned), movement (located and reference objects moving together or static), orientation (cars facing same way or facing each other) and post-position (takana, jäljessä or perässä). Significant main effects of movement, $F = 5.61$, $MSE = 3.42$, $p < .05$, and orientation, $F = 4.74$, $MSE = 3.32$, $p < .05$, were found, both in the same direction as those for *behind*. Furthermore, the interaction between movement and orientation was also significant, $F = 7.04$, $MSE = 2.27$, $p < .05$, again mirroring that found with *behind*. An effect of movement was present when the cars were facing each other ($M = 6.75$ for moving scenes and $M = 6.26$ for static scenes) but not when the cars were facing the same way ($M = 6.70$ for moving scenes and $M = 6.72$ for static scenes).

Of most interest are the interactions with postposition. A significant interaction between movement and postposition was found to be significant, $F = 6.32$, $MSE = 1.20$, $p < .01$ (displayed in Figure 3). Follow-up analyses

Table 4

Mean Ratings (and Standard Deviations) for Takana (Normal Characters), Jäljessä *(Underlined Characters) and* Perässä *(Italic) in Finnish*

	Misaligned	Aligned
Cars Moving Together		
Facing same way	6.66 (0.70)	6.71 (0.92)
	6.68 (0.98)	6.91 (0.54)
	6.65 (0.91)	*6.58 (1.31)*
Facing each other	6.60 (1.02)	6.83 (0.57)
	6.68 (0.89)	6.86 (0.67)
	6.67 (0.77)	*6.83 (0.53)*
No Movement		
Facing same way	6.78 (0.57)	6.91 (0.20)
	6.76 (0.54)	6.53 (1.45)
	6.63 (0.72)	*6.71 (0.68)*
Facing each other	6.66 (0.96)	6.61 (1.34)
	6.10 (1.92)	5.95 (2.19)
	6.05 (1.79)	*6.21 (1.62)*

revealed significant effects of movement for *jäljessä* ($p < .001$) and *perässä* ($p < .01$), but not for *takana* ($p > .05$). This is in line with the prediction made by Nikanne that some post-positions are marked for movement while others are not. None of the other main effects or interactions were significant.

General Discussion

For the first time the experiment reported reveals the interplay between a range of geometric parameters (alignment and orientation) and movement on the acceptability of "in front of" and "behind" terms in English and Finnish.

Considering "in front of" terms first, the results for *in front of* in English and *edellä* and *edessä* in Finnish were very similar. When cars were facing in the same direction highest ratings were given for scenes where the cars were aligned and far apart, and lowest ratings were given when they were near and misaligned. These findings are consistent with those found by Landau (1996) for *in front of*, and those found for other projective terms such as *above* (Hayward & Tarr, 1995; Logan & Sadler, 1996).

In relation to movement, *in front of* and *edellä/edessä* are influenced by movement in two ways. When there is a conflict between reference frames (when cars are facing each other), movement increases the acceptability of all three adpositions irrespective of the relative positions of the objects (i.e., at both levels of alignment). This is likely to be because under such circumstances movement instantiates the accidental intrinsic frame (which allows the intrinsic front of the located object to be the part that is at the front on a moving plane; cf Jackendoff, 1996), and therefore potential conflicts between the intrinsic fronts of the located and reference object are overridden. However, when there is no conflict between reference frames (when the cars are facing the same way), movement affects the acceptability of *edellä/edessä* at both levels of alignment, and movement affects the acceptability of *front of* also, but only when the cars are positioned in the weakest geometric region (i.e., when the cars are misaligned). Furthermore, the results were in the opposite direction to that predicted by Nikanne (2003) – movement leads to a decrease in the acceptability of *in front of* and *edellä/edessä* under these circumstances. This reduction in ratings may be because movement provides information that the cars are constantly misaligned.

The results for "behind" terms were similar. For "behind" terms in Finnish, the results partially support Nikanne's claim; ratings for *jäljessä* and *perassä* for moving scenes were reliably higher than ratings for static scenes, though there was no difference for *takana*. However, although the differences were statistically significant for *jäljessä* and *perassä*, ratings were still relatively high for static scenes indicating that the terms, although less appropriate, are still nevertheless not inappropriate to describe static objects.[2] Furthermore, the two-way interaction between movement and orientation was significant, indicating that the effect of movement for *jäljessä* and *perassä* only occurs when the cars are facing each other. Thus movement does not influence the acceptability of *jäljessä* and *perassä* in the way in which Nikanne predicted, although it is the case that there is no effect of movement for *takana*.

For *behind* in English, in relation to geometry, no main effect of alignment was found, suggesting that *behind* is less sensitive to changes in geometry than *in front of*. However, as with *jäljessä* and *perassä* when there is a conflict between reference frames (when cars are facing each other), movement increases acceptability irrespective of the relative positions of the objects (i.e., at all levels of alignment). No effect of movement was found for *behind* when the cars were facing in the same direction.

The results show that for "in front of" and "behind" terms in both English and Finnish (with the exception of *takana* in Finnish), the only effects of movement occur when cars are facing each other. Thus, in line with previous results found by Carlson-Radvansky and Radvansky (1996), the orientation of the located object is important for "in front of" and "behind" terms, but only in relation to reference frame selection. Motion allows the inhibition of other possible

[2]The analyses reported here did not include analyses of "near/far" and analyses of "in front of" and "behind" terms in clearly inappropriate locations. An examination of this data revealed that participants did rate terms that are clearly inappropriate with low ratings (including several mean ratings of 1, indicating that all participants gave the lowest rating possible). Therefore, the results reported are not ceiling effects.

reference frames, and therefore both "behind" and "in front of" terms become more acceptable when cars are facing each other when the accidental intrinsic frame is triggered. Dynamic-kinematic routines do not increase acceptability of *in front of/behind* in English, or *edellä/edessä/perässä/jäljessä* in Finnish (contrary to Nikanne's prediction for Finnish).

The striking similarities in the effects of movement across languages suggest different classes of projective adpositions might be subject to varying degrees of extra-geometric constraints. For example, *in* and *on* have both been shown empirically to be influenced by both geometric and dynamic-kinematic constraints (e.g., Garrod et al., 1999; Richards et al., 2004), as have *over*, *under*, *above*, *below* in English (Coventry et al., 2001) and *sobre*, *encima de*, *debajo de* and *bajo* (the equivalent prepositions) in Spanish (Coventry & Guijarro-Fuentes, 2004). For *in* and *on*, relative (continguous) movement of located and reference objects (e.g., a pear on top of other fruit in a bowl shown moving with the bowl and fruit at the same rate) increases the appropriateness of these terms (Coventry, 1998; Garrod, Ferrier & Campbell, 1999), and these findings have also been shown to be present in children as young as three-and-a-half years using a production paradigm (Richards et al., 2004). For *over*, *under*, *above, below* and their equivalent prepositions in Spanish, predicted movement (whether rain will fall on an umbrella or a man) is associated with increased acceptability of these terms. However, for "in front of" and "behind" terms it would appear that geometry is primary, and that movement is only a means of assisting reference frame assignment. The reason for this apparent difference might be a result of the axes involved for these terms.

While *in*, *on*, *over*, *under*, *above* and *below* all involve the vertical (gravitational) axis, *in front of* and *behind* involve the horizontal axis. It may be the case that the gravitational plane (the most dominant axis) is most associated with influences of dynamic-kinematic routines given the fact that objects in this plane fall towards the earth. Understanding the forces objects exert on each other in this plane is most essential for predicting how objects are likely to change position. There is certainly evidence that infants have emerging knowledge of gravity and the forces associated with it from just a few months of age (e.g., Kim & Spelke, 1992; Needham and Baillargeon, 1993). For example, Needham and Baillargeon (1993) have shown that 4.5-month infants expect an object to fall when its support is removed.

It is also the case that vertical projective terms have been shown to be differentially influenced by geometric and dynamic-kinematic routines (e.g., *over* and *sobre* are more influenced by dynamic-kinematic routines than *above* and *encima de*). These findings indicate that when a language has more than a single lexical item to describe a spatial relation, those items are likely to give different weights to geometric and extra-geometric constraints. The evidence from Finnish lends some support to this; Finnish *perässä* and *jäljessä* on the one hand do appear to mark for movement (albeit not in the way Nikanne predicted), while *takana* does not. At the same time *edellä* and *edessä* are distinguishable from each other in that *edellä* is preferred to *edessä* when the cars are facing in the same direction.

Although in this study we have not found substantial differences between English and Finnish as predicted by Nikanne (2003), and have found no evidence for the importance of dynamic-kinematic routines for these terms, it is possible that such effects may be found with other materials and scenarios. The roundabout scenario brings with it reference frame ambiguities, which may then limit the extent to which dynamic-kinematic routines are applied. Nevertheless, the present findings indicate a delicate interplay between a range of geometric and extra-geometric constraints. Using spatial language involves putting together both geometric and extra-geometric constraints, weighted by the specific term under consideration, and by the information present in the scene to be described. The subtleties in how a language puts these constraints together are affected by both the number of lexical items available in that language and the spatial constraints associated with those terms, such as the axis under consideration. The interplay between these constraints merits much closer attention cross-linguistically.

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