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How Relative is the Relative Frame of Reference? Front and back in Norwegian, Farsi, German, and Japanese

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Abstract

Across languages, people differ in which of the three basic frames of reference (FoRs) they prefer when describing spatial relations: absolute, intrinsic, or relative. But how much variation is there with regard to the *relative* FoR, which is anchored in the observer and occurs as one of three variants? Is the *reflection* variant canonical, as assumed by many scholars? And how are objects in a person's back referred to: by *turning* towards the objects? Results from two studies, one with speakers of Norwegian and Farsi, the other with speakers of German and Japanese, reveal that reflection is not canonical, but that translation and even rotation are used as well. In addition, turning towards objects arranged in a person's back is very rare; what people use instead is a backward projection strategy that goes without rotation.

Keywords: Spatial cognition, frames of reference (FoR), relative FoR, cross-linguistic study.

Introduction

“Where is the ball in relation to the box?” In order to answer questions like this, we have to establish a coordinate system—a frame of reference (FoR)—that allows us to derive a specific response such as “The ball is *in front and to the right* of the box.” Across languages, people differ in the frame of reference they preferentially adopt. Variation has been documented especially with regard to which of the three *basic* FoRs is used: the *absolute* FoR anchored in a superordinate field like the cardinal directions, the *intrinsic* FoR anchored in a reference object like an arrow, or the *relative* FoR anchored in an observer (Levinson, 2003; Majid et al., 2004; Senft, 1997). Less attention has been devoted to the variants of the relative FoR, despite the fact that variation in relative referencing has been known since Hill's (1982) comparison of English and Hausa speakers.

This paper adds to a survey exploring variation in the use of the relative FoR in different languages (for results on German, English, Mandarin Chinese, and Tongan, see Beller et al., 2015), by extending the set of sampled languages. In two studies, one with speakers of Norwegian and Farsi, and another with speakers of German and Japanese, we inspected which variant of the relative FoR speakers of these languages apply in frontal and dorsal tasks with objects laid out in front of or behind an observer.

Variants of the Relative Frame of Reference

Frames of reference are used to describe the position of a figure object F in reference to a ground object G. In contrast to the absolute and intrinsic FoR, the relative FoR requires

to do so from an observer's viewpoint V. As objects can be in front of or behind the observer, the distinction between frontal and dorsal is indispensable.

FoRs in Frontal Settings

Constructing a relative frame of reference requires the coordinate system that is originally anchored in the observer—his or her FRONT/BACK and LEFT/RIGHT—to be projected onto the ground object G. In frontal settings, this can be done in three ways (Levinson, 2003): The coordinate system can be *translated* into G so that FRONT is assigned in gaze direction of the observer to the space beyond G (see Figure 1A). It can be *reflected* in G so that FRONT is assigned to the space between the observer and G (Figure 1B). In both cases, assignment of LEFT and RIGHT remain unaffected. Finally, it can be *rotated* in G by 180°; in this case, FRONT is, again, assigned to the space between the observer and G, but assignment of LEFT and RIGHT are swapped (Figure 1C).

Of these variants, reflection is often assumed to be the canonical one (Clark, 1973; Grabowski & Miller, 2000; Janzen et al., 2012). In our cross-linguistic survey (Beller et al., 2015, cf. Table 3, p. 11), such a preference for reflection was found most strongly among speakers of German (89%) and English (73%), whereas speakers of Mandarin Chinese and Tongan clearly preferred translation (64%) over reflection (24%). The rotation variant was chosen rarely in

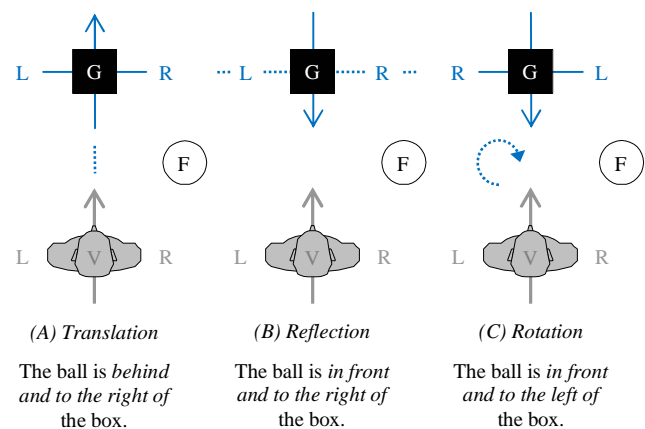


Figure 1: Variants of the relative FoR for frontal settings (according to Levinson, 2003); L/R: left/right; F/G: figure/ground; V: viewpoint of the observer.

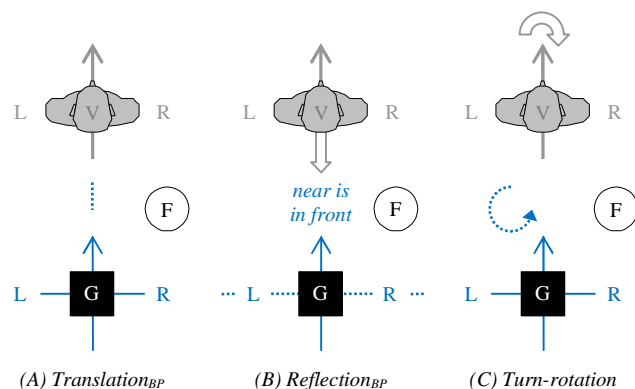
all four languages. Extending our survey to other languages so as to broaden our knowledge with regard to intra- and cross-linguistic variation in the use of these variants of the relative FoR is the first aim of the current paper.

FoRs in Dorsal Settings

Research on the relative FoR has focused nearly exclusively on how people describe relations of objects that are laid out *in front of* an observer—for obvious reasons the most natural situation—although adopting someone’s perspective already includes the distinction between what is in front of and what is behind that person. But how, if at all, would objects laid out *behind* that person be referred to?

One hypothesis put forward by Grabowski and Miller (2000) is that people refrain from referring to objects in their back. Rather, they turn around toward the objects, thereby converting the dorsal into a frontal setting, and then employ the FoR they prefer for frontal settings. However, the first studies on dorsal references (Beller et al., 2015, 2016) provided only weak evidence for this *turn hypothesis*. Despite participants’ preferences for reflection or translation in frontal tasks, only a few responses in dorsal tasks were in accordance with the corresponding strategies *turn-reflection* and *turn-translation*. What most participants seemed to do instead was a kind of *backward projection* of the observer’s coordinate system (without rotating the observer’s perspective) either in a back translation version (Figure 2A) or a reflection “with eyes in the back of one’s head” (Figure 2B).

For logical reasons, both of these backward projection strategies lead to the same responses as the *turn-rotation* strategy (turn the perspective and apply the rotation variant to the resulting frontal setting; see Figure 2C). The reasons for why we assumed that the participants applied backward projection were twofold: First, these strategies do not necessitate two laborious (mental) rotations, and second, participants applied the rotation variant (Figure 1C) only rarely in frontal tasks—why should they do so in dorsal



“The ball is *in front and to the right of* the box.”

Figure 2: Three variants of the relative FoR for dorsal settings (Beller et al., 2015); BP: backward projection.

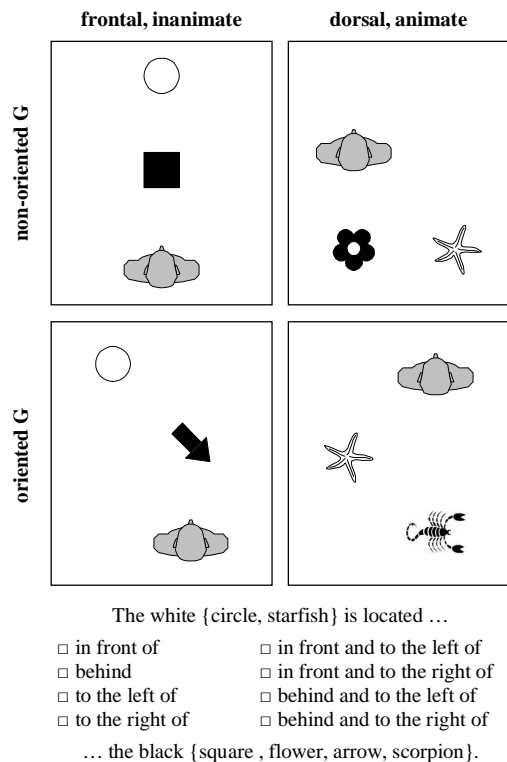


Figure 3: Four example items (Beller et al., 2015, p. 6).

tasks? Exploring backward projection further, as compared to the turn-hypothesis, is the second aim of the current paper.

Study 1

The first study was implemented as a paper-and-pencil survey that followed the design described in Beller et al. (2015) and included two languages from the Indo-European language family: Norwegian from the Germanic branch and Farsi from the Indo-Iranian branch.

Methods

Materials. The materials were the same as in Beller et al. (2015): twelve items in each of two conditions (*frontal* and *dorsal*), six with a non-oriented ground object (three depicting inanimate objects, three depicting living beings) and six with an oriented ground object (again three depicting inanimate objects and three depicting living beings). Participants were asked to indicate for each item the relation between figure F and ground G from the viewpoint V of a depicted observer, by choosing one of eight options (*in front of*, *behind*, *to the left of*, *to the right of*, and combinations of *in front of/behind* and *to the left/right of*). Four example items are shown in Figure 3. All materials were translated into Norwegian and Farsi by bilinguals.

Participants. The Norwegian sample consisted of 64 students from the University of Bergen (51 female; age $M = 23.3$ years, $SD = 5.3$), and the Farsi sample of 130 participants, most of them students from the Universities of Teheran, Schiraz, and Ghazwin, but also some non-students (88 female; age $M = 26.8$ years, $SD = 15.9$).

Design and Procedure. For each of the two conditions (frontal vs. dorsal), two item orders were prepared: The first one started with the six non-oriented items (in a random order) and then proceeded with the six oriented items (also in a random order); the second order was the exact reversal and thus started with the six oriented items. The eight response options were always presented in the same order. A between-subjects design was used. Participants were assigned randomly (but equally) either to the frontal or to the dorsal condition; the two item orders per condition were balanced in each subgroup. Participants were tested individually or in small groups, and were instructed to work on all tasks in the given order.

Results and Discussion

In the frontal condition, we distinguished between the three variants of the relative FoR: translation, reflection, and rotation (Figure 1). In the dorsal condition, we distinguished between three variants according to the turn-hypothesis: turn-translation, turn-reflection, and turn-rotation, the latter one being equivalent to two backward projection strategies, translation_{BP} and reflection_{BP} (Figure 2). For items with an oriented ground object, we also considered the intrinsic FoR.

In a first step, we checked the two samples for differences in the mean number of responses that are *not* covered by one of these FoRs. Overall, this number of “unexplained responses” was fairly low ($M = 8.6\%$; Table 1). An analysis of variance with two between-subjects factors, *language* (Norwegian vs. Farsi) and *perspective* (frontal vs. dorsal), and one within-subject factor *ground object* (non-oriented vs. oriented) indicated no significant effects (all $F(1,190) < 1.53$; $p \geq .218$; $\eta^2 \leq .008$), suggesting that neither the

Table 1: Frequency (%) of responses that are not covered by one of the FoRs under scrutiny in Study 1 and Study 2.

	Type of item	Norwegian	Farsi
Study 1	Frontal, non-oriented	5.7	10.6
	Frontal, oriented	8.3	10.1
	Dorsal, non-oriented	7.8	10.7
	Dorsal, oriented	7.3	8.6
	Type of item	German	Japanese
Study 2	Frontal, non-oriented	3.7	3.7
	Frontal, oriented	4.8	3.5
	Dorsal, non-oriented	4.0	2.6
	Dorsal, oriented	4.2	3.5

Table 2: Individual consistency in FoR adoption (in % of items) in Study 1 and Study 2.

	Type of item	Norwegian	Farsi
Study 1	Frontal, non-oriented	88.5	79.5
	Frontal, oriented	85.4	68.2
	Dorsal, non-oriented	87.0	85.2
	Dorsal, oriented	78.6	68.5
	Type of item	German	Japanese
Study 2	Frontal, non-oriented	93.5	87.3
	Frontal, oriented	89.8	82.1
	Dorsal, non-oriented	92.6	90.7
	Dorsal, oriented	91.2	83.9

unusual dorsal perspective nor the type of ground object influenced the coverage of responses by the FoRs under scrutiny in the two samples alike.

In the next step, we determined whether the individual participants adopted one FoR consistently and, if so, which one. To this end, we counted for each participant how often each FoR variant could be coded in each of the four blocks of six items (frontal non-oriented, frontal oriented, dorsal non-oriented, and dorsal oriented). For example, if reflection could be coded on 6 out of the 6 frontal oriented items, consistency would be 100% for reflection; if reflection could be coded on 5 items and translation on 1 item, consistency would be 83.3% for reflection and 16.7% for translation; etc. We then used the *maximum* of these values (among the different FoR variants) as estimate of a participant’s consistency in FoR adoption across the items of the respective block (100% and 83.3% in the examples). Mean consistency values are displayed in Table 2.

Overall, FoRs were adopted with a mean consistency of 80.1% across the two samples. In other words: Participants adopted their individually preferred FoR in 4.81 of 6 items of a block. An analysis of variance with two between-subjects factors, *language* (Norwegian vs. Farsi) and *perspective* (frontal vs. dorsal), and one within-subject factor *ground object* (non-oriented vs. oriented) indicated three significant effects: Consistency was generally higher for the Norwegian speakers than for the Farsi speakers (84.9% vs. 75.3%; $F(1,190) = 11.3$; $p = .001$; $\eta^2 = .056$); it was higher for non-oriented items than for oriented items (85.1% vs. 75.2%; $F(1,190) = 31.8$; $p < .001$; $\eta^2 = .144$); and there was an interaction of the two factors *language* \times *ground object* ($F(1,190) = 5.6$; $p = .019$; $\eta^2 = .029$). Thus, the possibility of applying an additional FoR (here: intrinsic) was a source of inconsistency, but to a different extent in the two languages. Interestingly, the unusual dorsal perspective *per se* did not matter: Consistency did not differ significantly between the frontal and the dorsal condition (84.4% vs. 79.8%; $F(1,190) = 0.045$; $p = .832$; $\eta^2 < .001$).

Finally, we identified each participant’s preferred FoR as the one FoR variant that was coded (a) more often than all others and (b) in at least 4 out of the 6 items of a block (i.e.,

Table 3: Preferred FoR (in %), adopted in at least 4 out of 6 items of a block (frontal non-oriented, frontal oriented, dorsal non-oriented, and dorsal oriented) in Study 1 and Study 2.

FoR	Study 1				Study 2			
	Non-oriented G		Oriented G		Non-oriented G		Oriented G	
	Norwegian	Farsi	Norwegian	Farsi	German	Japanese	German	Japanese
<i>Frontal items</i>	(N = 32)	(N = 66)	(N = 32)	(N = 66)	(N = 140)	(N = 109)	(N = 140)	(N = 109)
Intrinsic	n.a.	n.a.	3.1	19.7	n.a.	n.a.	2.9	4.6
Translation	21.9	28.8	15.6	18.2	7.1	48.6	4.3	45.9
Reflection	71.9	40.9	71.9	16.7	88.6	36.7	85.0	28.4
Rotation	—	10.6	—	4.5	0.7	1.8	—	0.9
No preference	6.3	19.7	9.4	40.9	3.6	12.8	7.9	20.2
<i>Dorsal items</i>	(N = 32)	(N = 64)	(N = 32)	(N = 64)	(N = 140)	(N = 109)	(N = 140)	(N = 109)
Intrinsic	n.a.	n.a.	6.3	18.8	n.a.	n.a.	3.6	6.4
Turn-translation	3.1	—	—	—	—	1.8	—	2.8
Turn-reflection	3.1	—	—	—	5.7	2.8	6.4	2.8
Translation _{BP} /reflection _{BP} /turn-rotation	81.3	82.8	71.9	40.6	88.6	89.0	85.7	78.9
No preference	12.5	17.2	21.9	40.6	5.7	6.4	4.3	9.2

Note. BP: backward projection; n.a.: not applicable; modal response printed in **bold** face.

with a consistency of $\geq 66.7\%$). Participants' preferred FoRs are presented in Table 3. Log-linear analyses of FoR preferences revealed differences between the two languages for the two blocks of frontal items (non-oriented: $G^2 = 12.7$; $df = 3$; $p = .005$; oriented: $G^2 = 33.7$; $df = 4$; $p < .001$), and for the block of oriented dorsal items ($G^2 = 8.9$; $df = 2$; $p = .012$), but not for the block of non-oriented dorsal items ($G^2 = 4.7$; $df = 3$; $p = .194$).

If adopting the *intrinsic* FoR was possible, some participants preferred this FoR¹, particularly in the Farsi sample (mean percentage across all items with an oriented G for Norwegian: 4.7%; Farsi: 19.2%). Other participants seemed to change their referencing strategy item-specifically, as indicated by the increased number of participants with no clear preference for any FoR variant as compared to the items with a non-oriented ground object.

Among the variants of the *relative* FoR for *frontal* tasks, both translation and reflection were adopted, but to a different extent in the two samples. The reflection variant prevailed most strongly among the Norwegian speakers (mean percentage across all frontal items for Norwegian: 71.9%; Farsi: 28.8%), while translation was preferred by a substantial proportion of speakers in both samples (Norwegian: 18.8%; Farsi: 23.5%); the rotation variant, in contrast, was confined to some Farsi speakers (7.6%).

Among the variants of the *relative* FoR for *dorsal* tasks, one variant clearly stood out, namely the one that is indicative of the application of backward projection and turn-rotation (Figure 2). Its frequency (mean percentage across

all dorsal items for Norwegian: 76.6%; Farsi: 61.7%) approximates the sum of translation, reflection, and rotation from the frontal tasks. But since the factor *perspective* was implemented between-subjects, the frontal and dorsal data cannot be related to one another on an individual basis, which would have provided a stronger argument in favor of this correspondence. In either case, the two FoR variants predicted by the turn-hypothesis—turn the view towards the objects and then apply the FoR preferred for frontal settings (i.e., reflection or translation)—were adopted very rarely.

In sum, Study 1 demonstrated that the reflection variant of the relative FoR is not canonical. While being the most frequent FoR in frontal tasks, the translation variant is adopted as well, and some participants even adopted the rotation variant. Participants' dorsal references suggested backward projection as the main strategy, but the data are not fully conclusive due to the between-subjects design.

Study 2

In order to allow us to relate a participant's referencing preference in dorsal tasks to that in frontal tasks, the second study included *perspective* (frontal vs. dorsal) as a within-subject factor. The study was implemented as an online survey and compared two languages from different language families: German, another Germanic language, and Japanese from the Japonic language family.

Methods

Materials. The items were the same as in Study 1. The materials were translated from German into Japanese by bilinguals and were implemented as a web-based online questionnaire.

¹ Inspecting the oriented items with inanimate objects versus living beings indicated no differences in how often the intrinsic FoR was applied. The two types of items were therefore pooled.

Participants. The German sample consisted of 140 student and non-student participants (105 female; age $M = 27.3$ years, $SD = 10.9$), and the Japanese sample of 109 student and non-student participants (64 female; age $M = 28.5$ years, $SD = 10.4$, with 15 not indicating their age).

Design and Procedure. The two perspectives (frontal vs. dorsal) were implemented within-subject. Which came first was assigned randomly for each participant. Within each perspective, non-oriented and oriented items were presented in blocks, and within each block in random order.

Results and Discussion

The data were analyzed in the same way as in Study 1. In the first step, we checked the two samples for differences in the mean number of responses that are *not* covered by one of the FoRs under scrutiny. Overall, this number of “unexplained responses” was very low ($M = 3.7\%$; Table 1) and lower still than for Norwegian and Farsi. An analysis of variance with the between-subjects factor *language* (German vs. Japanese) and two within-subject factors, *perspective* (frontal vs. dorsal) and *ground object* (non-oriented vs. oriented), indicated no significant effects (all $F(1,247) < 1.9$; $p \geq .171$; $\eta^2 \leq .008$). Neither the unusual dorsal perspective nor the type of ground object influenced the coverage of responses by the FoRs under scrutiny in the two samples alike.

Then, we checked how consistently each FoR variant was adopted. Overall, FoRs were adopted with a mean consistency of 88.9% across the two samples (Table 2). In other words: Participants adopted their individually preferred FoR in 5.33 of 6 items of a block. An analysis of variance with the between-subjects factor *language* (German vs. Japanese) and two within-subject factors, *perspective* (frontal vs. dorsal) and *ground object* (non-oriented vs. oriented), detected the same three effects as in Study 1: main effects of language and ground object, and an interaction of the two factors. Consistency was higher for the German speakers than for the Japanese speakers (91.8% vs. 86.0%; $F(1,247) = 15.2$; $p < .001$; $\eta^2 = .058$). It was also higher for non-oriented items than for oriented items (91.0% vs. 86.8%; $F(1,247) = 32.2$; $p < .001$; $\eta^2 = .115$), indicating again that the possibility of applying the intrinsic FoR was a source of inconsistency, but to a different extent in the two languages (as reflected in the interaction; $F(1,247) = 5.1$; $p = .024$; $\eta^2 = .020$). And, as in Study 1, the unusual dorsal perspective *per se* did not matter: Consistency was nearly the same for the frontal items as for the dorsal items (88.2% vs. 89.6%; $F(1,247) = 2.258$; $p = .134$; $\eta^2 = .009$).

Participants’ preferred FoRs are shown in Table 3. Log-linear analyses of FoR preferences indicated differences between the two languages for the same three item blocks as in Study 1: for the two blocks of frontal items (non-oriented: $G^2 = 78.3$; $df = 3$; $p < .001$; oriented: $G^2 = 96.0$; $df = 4$; $p < .001$), and for the block of oriented dorsal items ($G^2 = 10.4$; $df = 4$; $p = .034$), but not for the block of non-oriented dorsal items ($G^2 = 4.6$; $df = 3$; $p = .201$).

Table 4: Preferred FoR in dorsal item blocks depending on the preferred FoR in frontal item blocks in Study 2.

<i>Dorsal preference</i>	<i>Frontal preference</i>			
	Translation	Reflection	Rotation	Other
Turn-translation	3	—	—	2
Turn-reflection	2	20	—	1
BP/turn-rotation	106 _{BP}	278 _{BP}	3	40
Other	8	16	1	18
$N = 498$	119	314	4	61

Note. Data are summed over non-oriented and oriented item blocks and the two samples. BP: backward projection (translation_{BP} or reflection_{BP}); the category *other* includes participants with *no preference* (from all tasks) and with a preference for the intrinsic FoR (from tasks with an oriented G). Grey cells: Responses according to the turn-hypothesis.

If adopting the *intrinsic* FoR was possible, again some participants preferred this FoR (mean percentage across all items with an oriented G for German: 3.2%; Japanese: 5.5%), but less so than in the Farsi sample. Some participants also seemed to change their referencing strategy item-specifically, as indicated by the increased number of participants with no clear preference for any FoR variant as compared to the items with a non-oriented ground object.

Among the variants of the *relative* FoR for *frontal* tasks, translation and reflection were preferred most often, but again to a different extent in the two samples. The reflection variant prevailed most strongly among the German speakers (mean percentage across all frontal items for German: 86.8%; Japanese: 32.6%). This finding replicates data from a German sample collected with a paper-and-pencil questionnaire (Beller et al., 2015), thereby validating the methodological change to an online assessment (see Beller et al., 2015, 2016, for a broader discussion of the paper-pencil assessment and other methodological issues). In contrast, the translation variant prevailed among the Japanese speakers (German: 5.7%; Japanese: 48.6%). The rotation variant was adopted only by very few participants (German: 0.4%; Japanese: 1.4%).

Among the variants of the *relative* FoR for *dorsal* tasks, the variant indicating the application of backward projection and turn-rotation strongly dominated in the two samples alike (mean percentage across all dorsal items for German: 87.1%; Japanese: 83.9%).

The implementation of *perspective* as a within-subject factor in this study allows us to relate each participant’s preference in dorsal tasks to his or her preference in frontal tasks and thereby to disambiguate the dorsal response (cf., Beller et al., 2016). To this end, we cross-tabulated participants’ preferred FoRs for frontal and dorsal tasks (summed over non-oriented and oriented item blocks and the two samples). The results are reported in Table 4. Of the 498 preference pairs, 26 (5.2%) were indicative of the turn-hypothesis (grey cells). Most of these participants adopted the turn-reflection variant in line with the overall higher

prevalence for reflection. This provides some support for the turn-hypothesis. However, the vast majority of pairings (384 or 77.1%) pointed at backward projection as the prevailing strategy (translation_{BP}: 21.3%; reflection_{BP}: 55.8%).

In sum, Study 2 corroborated further that the reflection variant of the relative FoR is not universally adopted. While being the most frequent FoR used for frontal tasks in the German sample, the translation variant predominated in the Japanese sample. In line with the results from Beller and colleagues (2016), participants' dorsal references indicated backward projection as the main strategy.

General Discussion

The goal of this paper was to broaden our knowledge regarding intra- and cross-linguistic variation in the use of different variants of the relative FoR for spatial references in frontal and dorsal settings. In particular, we asked two questions: Do people have a canonical preference for the reflection variant of the relative FoR in frontal settings, as assumed by some scholars? And do people (mentally) turn around to an object configuration in their back and apply the FoR they prefer for frontal settings (turn-hypothesis)? Our findings indicate that neither is the case.

With regard to the first question, we detected a great deal of intra- and cross-linguistic variation in people's use of the relative FoR in frontal settings. The speakers of Norwegian, German, and Japanese exhibited high intra-individual consistency. Almost all participants applied the same variant of the relative FoR repeatedly for a whole set of tasks. Among the speakers of Farsi, consistency was lower, indicating more task-specific references, particularly in cases where the intrinsic FoR was also possible. With regard to the inter-individual *consensus* within the samples, we observed high consensus among the German speakers (i.e., most speakers adopted the same FoR variant as everybody else: reflection), moderate consensus among the Norwegian and Japanese speakers (some of which preferred the reflection variant, others the translation variant), and an even weaker consensus among the Farsi speakers (for which the data also indicate a rare but consistent use of the rotation variant). All in all, reflection and translation were the dominant variants of the relative FoR for frontal settings, replicating the general pattern found for German, English, Mandarin Chinese, and Tongan (Beller et al., 2015).

In spite of this diversity in *frontal* tasks, most participants converged on the very same response in the *dorsal* tasks. In most cases, this response could be attributed to backward projection strategies that are in line with people's frontal preference for translation or reflection, but get by without (mental) rotation, and are thus quite adaptive given the fact that mental rotation comes with substantial cognitive costs (Duran, Dale, & Kreuz, 2011; Shepard & Cooper, 1982).

Finally, the degree of linguistic variation is revealing in yet another regard. The intra-linguistic variation we found reflects the fact that spatial prepositions like "in front of" or "behind" are inherently underspecified. Nothing in these words tells us where exactly FRONT or BACK is. This can

only be established after having adopted a specific point of view, or frame of reference. Yet, *which* FoR a speaker adopts is either due to his or her individual preference or to conventions within his or her speech community. Viewed in this way, the variation we found is a *cultural* rather than a purely *linguistic* phenomenon.

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