EMPIRICAL MANUSCRIPT

Assessing the Comprehension of Spatial Perspectives in ASL Classifier Constructions

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Abstract

In ASL spatial classifier expressions, the location of the hands in signing space depicts the relative position of described objects. When objects are physically present, the arrangement of the hands maps to the observed position of objects in the world (Shared Space). For non-present objects, interlocutors must perform a mental transformation to take the signer's perspective ("Signer Space"). The ASL Spatial Perspective Comprehension Test (ASPCT) was developed to assess the comprehension of locative expressions produced in both Shared and Signer Space, viewed from both canonical Face-to-face and 90° offset viewing angles. Deaf signers ($N = 38$) performed better with Shared than Signer Space. Viewing angle only impacted Signer Space comprehension (90° offset better than 180° Face-to-face). ASPCT performance correlated positively with both nonverbal intelligence and ASL proficiency. These findings indicate that the mental transformation required to understand a signer's perspective is not automatic, takes time, and is cognitively demanding.

Locative expressions encode the spatial relationship between objects and may also require understanding the viewpoint of the speaker or signer. In English, the sentence "the cup is on the table" conveys the spatial relationship between the cup and table using the preposition "on." In contrast, in American Sign Language (ASL), spatial relationships are not conveyed through prepositions or locative phrases but rather via classifier constructions (also called depicting constructions) in which the handshape represents a class of objects (e.g., curved object, flat surface; Supalla, 1986; see also Schembri, 2003). The spatial relationship is indicated by where the classifier handshapes are placed with respect to one another in signing space. The orientation of the classifier handshape can also indicate the orientation of the referent object (e.g., the cup laying on its side). By convention, spatial descriptions are expressed from the signer's perspective (Pyers, Perniss, & Emmorey, 2015).

If both the signer and addressee can see the objects being described, the location and orientation of the signer's hands in signing space correspond to the location and orientation of objects in the observed physical world. Emmorey and Tversky (2002) referred to this situation as *Shared Space* because both the

signer and addressee each have views in which the space is shared between signing space and the described physical world. Figure 1A provides an illustration of Shared Space in which the objects within the scene are visible to both the signer and addressee. As can be seen, the spatial mapping between the signer's hands and the referent objects is the same for both the signer and addressee because the location of the signer's hands corresponds directly to the objects in the shared environment.

A signer might also refer to the position of objects within scenes that are recalled from memory or otherwise not visually available to the addressee. In this situation, the signer communicates the (imagined) scene from her perspective, which creates a type of conflict for the addressee. For example, to describe a remembered scene in which a person is to the left of a car, the signer would place the handshape classifier representing the person (the "V" handshape, representing an upright person) on her left and the handshape representing the car (the "3" handshape, representing a vehicle) on her right. If the addressee is facing the signer, the person handshape appears on his right and the vehicle handshape appears on his left (see Figure 1B). Therefore, the addressee must perform a mental transformation

Figure 1 Shared Space (A) entails co-observation of physically present objects by both the signer and addressee. In Signer Space (B), the signer describes an imagined (non-present) scene in which a car is on the right (indicated by the ASL vehicle classifier produced with the right hand) and a person is on the left (indicated by the ASL upright person classifier produced with the left hand). The addressee achieves the appropriate mental representation by accommodating the signer's perspective.

in order to understand that the person is on the left (and the car is on the right) in the scene being described by the signer. We will refer to this situation as *Signer Space*. In a standard face-to-face conversation, the mental transformation involves a 180° reversal or rotation along the horizontal plane.

In comparison to the direct mapping between the hands and physical objects that occurs with Shared Space, Signer Space appears to require an additional level of mental computation, which may contribute to an addressee's cognitive load. In the present study, we assessed whether the additional mental transformation involved in understanding Signer Space makes these descriptions more difficult to understand compared to Shared Space, where no such mental transformation is required (see Figure 1). However, it is possible that there may be no difference in the difficulty of understanding descriptions using Signer Space and Shared Space because (a) descriptions using Signer Space are quite common and (b) signers may have developed efficient heuristics for understanding Signer Space. It is possible that signers are less likely to use classifier constructions to describe objects in their immediate environment (i.e., using Shared Space), preferring to point to the location of the object, but may be more likely to converse about non-present referents using classifier constructions (i.e., using Signer Space). As such, signers may have developed specific heuristics to perform the mental transformation required to understand Signer Space with relative ease. One such heuristic might entail flipping the signed spatial relation in face-to-face conversation, such that whatever is seen to the left of a centerline is imagined on the right, and vice versa, using a cognitively-effortful strategy; however, subjective reports from native signers indicate that they "instantly" know how to interpret descriptions in Signer Space (Emmorey, Klima, & Hickok, 1998), suggesting the interpretation might be more automatic (e.g., Surtees & Apperly, 2012).

Another factor that might influence spatial scene descriptions is the relative position of the signer and addressee. The discussion above highlights the 180° transformation required to understand face-to-face descriptions in Signer Space. While facing one's addressee is likely the most common situation, signers are not always directly opposite each other, e.g., group

dinner table conversations, sitting side-by-side in a car, etc. If the addressee were positioned to side of the signer (at a 90° offset), the cognitive load involved in comprehending face-to-face Signer Space might be reduced. A 90° mental transformation is easier to perform than a 180° transformation, at least in nonlinguistic domains (e.g., Michelon & Zacks, 2006). Alternatively, because face-to-face conversation is commonplace and permits the flipping heuristic described above, face-to-face scene descriptions may be easier to understand than descriptions observed from the side (at a 90° angle). In this study, we assess whether a smaller angle of offset for the addressee reduces cognitive load (improving comprehension speed or accuracy) or whether the canonical nature of face-to-face conversations facilitates comprehension compared to a less canonical speaker-addressee position (i.e., a 90° offset).

Quinto-Pozos et al. (2013) contrasted different conversation perspectives (face-to-face vs. over-the-shoulder) in testing comprehension of Signer Space descriptions that used classifier constructions. This study employed a novel test, the ASL Perspective Taking Comprehension Test (ASL-PTCT), to assess perspective-taking skills when understanding this type of spatial language. The test was used to examine the spatial language abilities of a deaf native signer (age 17;1) who had deficits in nonlinguistic perspective-taking, compared to control participants who were typically developing deaf native signers. The sign model for this test was filmed producing two-object classifier constructions in Signer Space either (a) directly facing the camera, creating a canonical face-to-face situation or (b) over her shoulder. The over-the-shoulder viewing angle reduced offset between signer and addressee to 45° (rather than 180°). After each video, participants chose the object arrangement that matched the signed description from a set of four photographs. In Quinto-Pozos et al. (2013), the typically developing deaf signers ($n = 15$, $M_{age} = 16;9$) scored worse on the face-to-face canonical items (58% accuracy) compared to the over-the-shoulder items (71% accuracy) (see also Quinto-Pozos & Huo, 2013). The authors suggest that the difficulty with the face-to-face items may be due to the 180° mental transformation required to understand these descriptions. However, success on this test also required additional nonlinguistic mental rotation.

Specifically, the target image in the ASL-PTCT picture choice array was initially presented from the model's perspective, but later trials showed the correct target picture from different perspectives. For example, for the ASL description "the dog is to the right of the car," the right-left arrangement of the dog and the car would be maintained in the target picture, but rotated such that the car is seen as behind the dog. Quinto-Pozos et al. (2013) state that this manipulation was used to test signers' ability to imagine the correct object arrangement from various perspectives. This design, however, complicates typical linguistic processing by adding a mental rotation that must be performed in order to select the correct response.

We created a modified version of the ASL-PTCT that eliminated this additional mental rotation process and that allowed us to assess comprehension of Shared Space versus Signer Space and investigate different addressee viewing angles (90° and Face-to-face). Our task, the ASL Spatial Perspective Comprehension Test (ASPCT), presents participants with ASL spatial descriptions in four conditions: Shared and Signer Space in both the *Canonical Position* (viewed signing Face-to-face) and a 90° *Position* (viewed from the side). Each trial involved presentation of a video of a classifier construction expressing the spatial relation between two objects, followed by a set of four pictures. Instructions before each condition and visual cues within each video were specifically designed to promote either a Shared

Space or Signer Space interpretation of the ASL descriptions (e.g., signing directly to the participant or signing at a 90° offset to a friend off camera). These four conditions correspond to manipulations in both physical signer-addressee position (Face-to-face vs. 90°) as well as Communication Type (use of Shared vs. Signer Space).

Full comprehension of classifier constructions involves the integration of multiple pieces of information: object orientation, object arrangement, and perspective. Across all conditions, we tested the mapping of hand placement and orientation to the arrangement and orientation of the pictured objects (see Figure 2 for foil examples). When a signer uses a 3-handshape to represent a car, for example, the tips of the fingers correspond to the front of the car. To create an *orientation* foil for each trial, we rotated one of the two objects in the target display by 180°. Thus, participants had to distinguish, for example, between a car facing away from the signer versus a car facing toward the signer. To create an *arrangement* foil, we swapped the location of each item in the target display, forcing participants to distinguish between “to the right” and “to the left” as well as “in front” and “behind”. These two foil types allow us to compare comprehension of object location versus object orientation. We predict that signers may be more likely to incorrectly select an orientation foil than an arrangement foil because orientation can be unmarked (Emmorey, 1996). That is, signers may not always interpret the orientation of the classifier handshape as indicating the orientation of the referent object. Specifically, when signers use a phonologically neutral orientation (i.e., the citation form of the classifier handshape), the description need not be interpreted as expressing the orientation of the referent object. Finally, we created a 180° foil, in which the set of objects was rotated by 180°, showing the target object arrangement from the opposite perspective. In the Face-to-face condition, the 180° foil for a Shared Space trial shows the correct Signer Space interpretation, while the 180° foil for a Signer Space trial shows the correct Shared Space interpretation. The

latter case may be especially distracting, when the 180° foil directly maps onto the model’s production (see Figure 2). Signers may need to suppress the more immediate Shared Space representation as they perform the mental transformation required to interpret Signer Space. Thus, we predict that signers will be more likely to select the 180° foil in the Face-to-face Signer Space condition than in the Shared Space condition. By including foils for each of these facets of classifier construction comprehension, we are able to assess which aspects of these constructions are more difficult to understand and whether accuracy patterns interact with either physical position (Face-to-face vs. 90°) or Communication Type (Shared Space vs. Signer Space).

Methods

Participants

Thirty-eight deaf ASL signers (19 females; $M_{\text{age}} = 30.7$ years; $SD = 8.1$) were recruited from the community in San Diego, CA to participate in this study. Thirty were exposed to ASL from birth, and the remaining eight were exposed to ASL prior to age 6 ($M_{\text{age of acquisition}} = 1.9$ years, $SD = .58$).¹ Nine additional participants were run, but were excluded from the analyses due to strategic, systematic selection of an incorrect answer. That is, for at least one condition, these participants selected the 180° foil significantly above chance, and the correct answer was selected significantly below chance. We took this pattern to indicate that these participants misunderstood or did not sufficiently attend to the instructions.

Materials

Participants saw four blocked conditions in a 2×2 design: Communication Type (Shared Space, Signer Space) crossed by Physical Position (Face-to-face, 90°). Communication Type (Shared or Signer Space) was differentiated by whether or not

Figure 2 Sample Signer Space stimulus item with the correct response picture and foils. The “3” handshape, the model’s right hand, indicates that the vehicle is on the right, facing inward. The “bent-V,” the model’s left hand, indicates that the small animal is on the left, also facing inward.

the sign model looked at a laptop to view the scenes she described, as well as by a change of the model's clothing (see Figure 3). To establish Shared Space interpretations, the instructions provided a sample item in which the sign model described objects that were visible on a small table in front of her as if the participant were present in the room with the sign model. All Shared Space stimuli (both practice and test items) were filmed with the video zoomed in on the sign model so that the table with the objects was out of frame. To establish Signer Space interpretations, the instructions provided a sample item in which the sign model held up a laptop computer to show the image that she would subsequently describe. All Signer Space stimuli were filmed with the laptop computer visible on-screen, but turned in such a way that the image displayed on the laptop was visible only to the sign model (i.e., participants could only see the back of the laptop). Two practice trials with feedback immediately followed each instruction video, which required participants to adopt the appropriate Communication Type (Shared Space or Signer Space). Each condition contained 18 experimental trials. To establish a similarly naturalistic scenario for both Face-to-face and 90° stimuli, instruction videos either stated that the stimuli would be signed to the participant directly (Face-to-face) or to a friend off-screen (90° offset). In the latter case, the model was seated facing to her left, perpendicular to the camera (see Figure 3). The model's off-screen interlocutor was shown during instructions, but remained off-screen for subsequent stimuli.

Instruction videos also presented each of the three possible referent objects (a toy car, a dog, and a man), by showing short clips of each toy rotating 360°. As each toy was shown, the model produced the corresponding ASL classifier handshape. Figure 4 displays the vehicle, small animal, and "standing human"

Figure 3 (A) and (B) show screen shots of Shared Space video stimuli. (C) and (D) show screen shots of Signer Space video stimuli. (A) and (C) show the canonical Face-to-face condition, and (B) and (D) show the 90° condition. The picture arrangement for all Signer Space descriptions is shown in (E). The picture arrangement for the 90° Shared Space condition, (B), is shown in (F). All videos and pictures were shown in color during the experiment.

handshapes that were used to represent these objects, along with pictures of the objects. Each classifier handshape maps onto the object with an intrinsic frame of reference, e.g., the front of the car maps to the index/middle fingertips for the vehicle classifier, the front of the knuckles maps to the front of the dog, and the back of the hand maps to the front of the man. Objects could be upright, upside down, on their left or right side, or on their front or back side.

For each trial, the participant saw a video of a signer producing a two-object classifier construction without any lexical labels. Although lexical labels are typically used to introduce novel referents immediately before the classifier construction, classifier constructions can be produced later in the discourse without the lexical labels. For this task, the instructions served to introduce each of the three possible referents whose locations and orientations were then described throughout the experiment. For each trial, the model's hands rose into the appropriate position, were held in place briefly, and then returned to rest position on her lap. In this construction, the location of each hand represented the location of a referent, and the two hands were placed in space simultaneously. Following the signed stimulus, a set of four pictures appeared on the computer screen. In the Shared Space condition, the participant was instructed to pick the answer that corresponded to location/orientation of objects on a table off-screen (i.e., from the participant's own perspective). Thus, to succeed on the Shared Space items, participants simply mapped from the signer's hands to the objects without any kind of perspective transformation. In the Signer Space condition, the participant was instructed to pick the picture shown on the laptop that the sign model was viewing and describing. Thus, the participant had to accommodate the perspective of the signer, performing a 180° mental transformation of the signed production. Participants selected their response with one of four side-by-side keys labeled A through D.

The four picture choices included the target picture as well as three foils, as described above (see Figure 2). The object orientation foil deviates from the target picture in that one of the two objects was rotated 180° about its y- or z-axis. For the arrangement foil, the spatial positions of the two objects were swapped. In the 180° foil, the correct object arrangement was pictured from the opposite perspective. For example, in the Face-to-face condition, the 180° foil represented the opposite Communication Type (e.g., adopting Shared space when the correct response required adopting the model's perspective in Signer space).

A number of steps were taken to ensure counterbalancing of conditions and trial types. First, conditions were counterbalanced

Figure 4 ASL classifier handshapes (above) and the corresponding object (below).

across participants for order of Communication Type (Shared Space, Signer Space) and Position conditions (Face-to-face, 90°). Participants saw either Shared or Signer space trials first. Face-to-face and 90° position conditions were nested within each communication condition, counterbalanced across participants with respect to order of presentation. Trial order was pseudorandomized such that no more than two trials in a row had the same correct answer (A, B, C, or D) or involved the same two objects (dog and car, man and car, etc.). Each of the three objects appeared 12 times for each condition. Finally, half of the trials for each condition involved a left/right relationship between the two objects and half of the trials involved a front/back relationship.

Procedure

An experimenter briefly explained the procedure to each participant in ASL to highlight first, that there would be different blocks of stimuli with different sets of instructions, and second, that between trials the participant should keep the index finger of their dominant hand resting on a sticker on the table. The sticker was located directly in front of the keyboard containing keys labeled A through D. This sticker procedure was developed after it was discovered that some pilot participants would physically copy and hold the sign model's production while considering the answer. While it may be a useful strategy for the task, we wanted to ensure that all participants were relying on internal linguistic processes, rather than overt strategic aids. An experimenter remained in the room to monitor progress, ensure comprehension of practice items, and remind participants to keep their finger on the table while watching videos.

Participants sat in front of an iMac (OSX 10.8, 21.5 inch screen) running Psyscope X B77 (Cohen, MacWhinney, Flatt, & Provost, 1993), which captured key presses and response times for each trial. Each condition began with an instruction video, asking the participant to respond as quickly and as accurately as possible. The instructions also informed participants that responses must be made within seven seconds after the end of the video.² For each condition, two practice items were presented with feedback. In any given trial, the participant saw a classifier construction involving two of three possible objects (car, dog, and man). After the video disappeared, the participant had to choose one of four pictures by pressing keys labeled A to D. Pictures were presented in color and occupied one quarter of the screen width or height (see Figure 3). Trials timed out after seven seconds if no response was made.

Finally, because ASPCT assesses a very specific domain of language, we wanted to determine whether performance on this test correlates with more general language abilities. Therefore, we also measured ASL proficiency using the 35-sentence version of the American Sign Language Sentence Reproduction Test (ASL-SRT; Supalla, Hauser, & Bavelier, 2014). The ASL-SRT asks participants to watch and repeat signed sentences, ranging from short, simple active declarative sentences to longer, more complex multi-clause sentences. Participant reproductions were filmed and awarded a point for each sentence that was exactly replicated.

We also wanted to determine the extent to which ASPCT performance is related to general cognitive ability. For a nonverbal intelligence measure, we administered the matrices subtest of the Kaufman Brief Intelligence Test, Second Edition (KBIT-2; Kaufman & Kaufman, 2013). The matrices subtest presents participants with a series of pictures of objects or geometric patterns, and participants are asked to complete the series (i.e., what comes next?) by selecting a picture from a multiple-choice array. The test progresses from simple to more difficult patterns that require

abstract nonverbal reasoning. The test is discontinued after four consecutive incorrect responses. Raw and standard scores were calculated according to the KBIT-2 manual. Standard scores were used for all analyses.

Results

Accuracy and reaction time were analyzed in separate 2 (Communication Type: Shared, Signer) $\times$ 2 (Position: Face-to-face, 90°) $\times$ 2 (Gender) repeated measures ANOVAs, each using gender as a between-subjects factor. Gender was included as a factor because of its known connection to performance on spatial tasks (e.g., Lawton, 1994; Tarampi, Heydari, & Hegarty, 2016). In addition, correlations between ASPCT performance (accuracy, reaction time, 180° foil selection) and nonverbal IQ (KBIT scores) and general ASL ability (ASL-SRT scores) were also conducted. The 180° foil selection was chosen as an additional variable in correlational analyses because it represents a perspective-selection error. Table 1 lists mean accuracy and RT for each condition, and the results are illustrated in Figure 5.

Accuracy

Participants were more accurate for the Shared Space (74%) condition compared to the Signer Space (69%) condition, $F(1, 36) = 4.51$, $p = .041$, $\eta_p^2 = .11$. Despite the atypical nature of the 90° position, participants were more accurate for the 90° condition (77%) compared to the Face-to-face condition (66%), $F(1, 36) = 32.06$, $p < .001$, $\eta_p^2 = .47$. However, these main effects were modulated by a two-way interaction, $F(1, 36) = 16.20$, $p < .001$, $\eta_p^2 = .31$. In the Signer Space condition, participants were significantly less accurate for the Face-to-face condition (59%) compared to the 90° condition (79%), $t(37) = -5.681$, $p < .001$. However, for the Shared Space condition, participants performed similarly across these two position conditions (73% and 75%, respectively, $t(37) = -.890$, $p = .379$). Males were marginally more accurate ($M = .76$, $SD = .11$) than females ($M = .67$, $SD = .16$), $F(1, 36) = 3.90$, $p = .056$, $\eta_p^2 = .10$, but Gender did not interact significantly with either Communication Type, $F(1, 36) = 1.09$, $p = .304$, $\eta_p^2 = .03$, or Position, $F(1, 36) = .424$, $p = .519$, $\eta_p^2 = .01$. Finally, we examined whether there were any differences in accuracy when comprehending left/right vs. front/back spatial relationships. Participants were less accurate for front/back arrangements (68%) than for left/right arrangements (74%), $t(37) = -3.93$, $p < .001$.

Reaction Time

Participants were significantly faster for Shared Space ($M_{RT} = 3749$ ms) compared to Signer Space (4003 ms), $F(1, 36) = 8.16$, $p = .007$, $\eta_p^2 = .19$. Thus, participants were faster to respond when selecting a picture from their own perspective, as opposed to that of the sign model. In contrast to accuracy, reaction times

Table 1. Mean (standard deviation) for accuracy (percent correct; Acc) and RT (ms) by communication type and position conditions

		Signer Space	Shared Space	Total
Face-to-face	Acc	59% (22)	73% (17)	66% (21)
	RT	4098 (844)	3710 (600)	3904 (756)
90°	Acc	79% (17)	75% (17)	77% (17)
	RT	3909 (668)	3788 (628)	3848 (647)
Total	Acc	69% (22)	74% (17)	71% (14)
	RT	4003 (762)	3749 (611)	3967 (535)

Figure 5 (A) Accuracy by communication type and position conditions. (B) Reaction time (ms) by communication type and position conditions. Error bars denote one standard error around the mean.

Table 2. Average percent (standard deviation) of foil selection by communication type and position conditions

Foil type	Signer Space		Shared Space		Total
	Face-to-face	90°	Face-to-face	90°	
180°	14.9 (13.6)	5.1 (9.6)	4.1 (6.5)	3.1 (5.1)	6.8 (5.8)
Arrangement Swap	8.3 (8.1)	1.9 (4.1)	2.5 (3.6)	2.5 (5)	3.8 (3.5)
Object Orientation	14.2 (9.9)	10.6 (8.3)	18.1 (10.5)	17.3 (12.3)	15.0 (7.5)
Omitted	4.2 (5.2)	3.2 (5.3)	2.8 (4.8)	2.5 (4)	3.2 (3.5)

showed no significant effect of either Position, $F(1, 36) = .747, p = .393, \eta_p^2 = .02$, or Gender, $F(1, 36) = 1.26, p = .269, \eta_p^2 = .03$. There was a marginal two-way interaction between Communication Type and Position, $F(1, 36) = 3.10, p = .087, \eta_p^2 = .08$. Similar to the accuracy results, a post-hoc paired *t*-test revealed that in the Signer Space condition participants were marginally slower in the Face-to-face condition (4098 ms) than in the 90° condition (3909 ms), $t(37) = 1.729, p = .092$, but RTs were similar for the two positions in the Shared Space condition (3710 ms and 3788 ms, respectively), $t(37) = .900, p = .374$. No other interactions approached significance (all $ps > .2$). Finally, we examined whether there were any differences in response time when comprehending left/right vs. front/back spatial relationships. Participants were slower for front/back arrangements (4061 ms) than for left/right arrangements (3873 ms), $t(37) = 3.76, p = .001$.

Error Types

Table 2 shows the distribution of error types across the Communication Type and Position conditions. The object orientation foil was the most frequent error choice overall across all conditions ($M = 15\%$) compared to each other foil type ($M = 4.6\%$).

Because the mental transformation involved in interpreting Signer Space is central to this investigation, we used the proportion of 180° foil responses for the following analysis. We conducted a Communication Type (Signer Space, Shared Space) by Position (Face-to-face, 90°), repeated measures ANOVA, with Gender as a between-subjects variable. Participants chose the 180° foil more often in the Signer Space condition (10.2%) compared to the Shared Space condition (3.5%), $F(1, 36) = 19.767, p < .001, \eta_p^2 = .35$. In other words, participants chose the 180° foil more often when the condition required them to accommodate the sign model's perspective. Participants also chose the 180° foil more often in the Face-to-face condition (13.4%) compared

to the 90° condition (4.9%), $F(1, 36) = 16.785, p < .001, \eta_p^2 = .32$. There was also a significant two-way interaction between Communication Type and Position, $F(1, 36) = 11.11, p = .002, \eta_p^2 = .24$. Within Signer Space, participants chose the 180° foil much more frequently in the Face-to-face condition (14.9%) compared to the 90° condition (5.1%); however, within Shared Space, participants chose the 180° foil equivalently across these two conditions (4.1% and 3.1%, respectively). There were no effects of Gender (all $ps > .13$).

Correlations

Age was significantly correlated with both ASPCT reaction time, $r(38) = .35, p = .030$, and accuracy, $r(38) = -.43, p = .007$; younger participants were both faster and more accurate. As a result, subsequent partial correlations controlled for age. Participants with high accuracy on ASPCT also showed high nonverbal intelligence (KBIT-2), $r(35) = .66, p < .001$, and high ASL fluency (ASL-SRT), $r(35) = .36, p = .031$. There were also marginal negative correlations between ASPCT reaction time and nonverbal intelligence, $r(35) = -.29, p = .081$, and ASL fluency, $r(35) = -.32, p = .053$. Participants with faster RTs tended to have higher nonverbal intelligence and higher ASL-SRT scores. However, nonverbal intelligence was unrelated to ASL fluency, $r(35) = -.25, p = .13$.

To further explore the relationship between accuracy on the ASL-SRT and ASPCT, we examined the nature of the repetition for the 14 items on the ASL-SRT that are optionally perspective-dependent. For example, for sentences in which the sign model associates a referent with a location on her right (e.g., THAT_{right} BIKE BROKE), participants could repeat the sentence by mirroring the model (producing THAT on their left) or they could perform the mental transformation needed to take the signer's perspective, i.e., reversing the observed production and articulating THAT on their right. For scoring purposes, either type of reproduction is considered correct because the spatial location

of the referent in these cases is not necessarily at issue. That is, the spatial location could simply be used to establish reference (no mental transformation required), rather than to indicate the spatial relationship between the referent and the signer (i.e., asserting that the bike is literally located on the right of the signer), in which case a mental transformation would be required (see Emmorey, Corina, & Bellugi, 1995, for discussion of the referential vs. topographic functions of signing space). Accuracy on these 14 sentences did not correlate with ASPCT accuracy, $r(35) = -.27, p = .11$. However, ASPCT performance was related to an individual's likelihood of reversing the production, $r(35) = .31, p = .064$. That is, those with high accuracy on ASPCT were marginally more likely to reproduce these sentences from the model's perspective; conversely, those who tended to mirror the sign model for these sentences had lower ASPCT scores.

Discussion

The ASL Spatial Perspective Comprehension Test (ASPCT) was designed to measure the comprehension of ASL classifier constructions for both Shared Space and Signer Space contexts. This test directly compares situations in which the arrangement of the hands must be mapped directly onto the target response, i.e., a Shared Space context, with situations in which participants are required to perform a mental transformation to accommodate the sign model's perspective, i.e., a Signer Space context. This test also directly compared the canonical Face-to-face context to a context with a less common 90° offset in which the model directed her signing to an addressee off camera (see Figure 3B, D).

Overall, participants were both faster and more accurate for Shared Space compared to Signer Space contexts. The additional mental transformation required for Signer Space appears to reduce both the speed and accuracy of understanding ASL classifier constructions that express viewpoint-dependent spatial relationships (i.e., left/right, front/back). In addition, participants also showed higher accuracy for Signer Space when the signer was facing an addressee off-screen, in the 90° perspective. In contrast, the sign model's position did not alter performance for the Shared Space context. Thus, when the hands directly map onto the objects in the target image, the position of the signer does not matter. When participants must accommodate the perspective of the model in Signer Space, they are more accurate when the model's signing space is offset by only 90° as opposed to 180°, which represents the more canonical Face-to-face context, but requires a greater degree of rotation.

In contrast to the intuition that signers "instantly" know the arrangement of objects in a spatial description using classifier constructions (Emmorey et al., 1998), the data in the present study suggest that some form of mental transformation must be applied to classifier constructions presented in Signer Space. While the exact nature of this mental rotation is still unknown, there are two interesting possibilities suggested in the present data. First, classifier construction comprehension may be akin to other kinds of nonlinguistic perspective-taking. Kessler and Thomson (2010) make the case that, in order to judge whether an object is to the left or the right of a model placed in different positions around a table, participants develop intermediate analog representations to map the model's body onto their own. The greater the offset between the model and participant, the longer it takes to make a left/right judgment and the greater the impact on accuracy. Alternatively, there may be unique difficulties at a 180° offset for ASPCT that one would not observe at lesser angles. In the Face-to-face Signer Space condition, the

180° foil was significantly more distracting than in other conditions. The high frequency of 180° foil selection in the Face-to-face Signer Space condition may be due to difficulty suppressing the egocentric representation depicted in this foil. To look for evidence of these possibilities, future studies could test more angles of model position (e.g., 40°, 60°, 120°, etc.) and look for either gradually increasing response times and error rates across increasing offset angles or similar error rates across various angles with 180° showing unique difficulty. A gradual change in performance would indicate an analog mental representation, while a more abrupt change would indicate that suppression of the egocentric representation plays a more important role in comprehending classifier constructions that are expressed using Signer Space.

There is some evidence that ASPCT performance recruits analog transformation abilities. Secora (2016) examined the performance of deaf signers on ASPCT, as well as a classic mental rotation task (Peters et al., 1995; Vandenburg & Kuse, 1978) and a visuospatial perspective-taking task (Shelton, Clements-Stephens, Lam, Pak, & Murray, 2011). In the mental rotation test, participants were shown a target line drawing of a three-dimensional block and selected two of four response pictures that could be mentally rotated to match the target drawing. The perspective-taking task presented participants with a model of three buildings surrounded by various colored blocks. Each block represented a perspective from which the buildings could be viewed. After exposure to the three buildings model, the participant was presented with various views of the model on a computer screen and asked to select the color block corresponding to the appropriate perspective shown in the picture. Secora (2016) found significant correlations between accuracy on the Signer Space condition in ASPCT and the mental rotation task, as well as between Signer Space ASPCT accuracy and the perspective-taking task. These correlations suggest that signers recruit non-linguistic perspective-taking and mental rotation abilities to support classifier comprehension in Signer Space contexts. Future research might examine the neural correlates of perspective-dependent classifier constructions to look for evidence that language comprehension recruits neural areas associated with perspective-taking or mental rotation.

While ASPCT is presented in a linguistic context using common ASL classifier handshapes, the orientation manipulation foil may have pushed the bounds of what is ordinarily required in understanding classifier constructions in day-to-day ASL conversations. Emmorey (1996) suggests that phonologically neutral classifier constructions (citation forms) may only express the existence of a referent at a location without explicitly specifying its orientation. Informal reports from participants in the present study reinforced this notion. Participants indicated that while all sentences presented made perfect sense, they were unaccustomed to attending to the orientation of the classifier handshape without some kind of additional pragmatic stress to emphasize the object's orientation. Therefore, it is perhaps unsurprising that the orientation foil was chosen more frequently than any other foil type. Nonetheless, participants did attend to the orientation of the classifier handshape since their choices were not evenly split between the correct response and the orientation foil.

We also found that participants made slightly more errors and were slower on trials in which the sign model expressed a front/back arrangement compared to a left/right arrangement. This result is somewhat surprising because front/back relationships are typically easier to comprehend than left/right relationships in both ASL (e.g., Martin & Sera, 2006) and spoken

languages (e.g., Johnston & Slobin, 1979). We speculate that the difficulty may have been due to the partial occlusion of one of the hands that occurs when depicting a front/back arrangement and/or a higher degree of visual “crowding” compared to the left/right arrangement.

The correlation results support the notion that comprehending spatial descriptions using classifier constructions is related to both linguistic ability (as measured by the ASL-SRT) and nonlinguistic cognitive ability (as measured by the KBIT-2). The relationship between ASPCT and more general nonverbal intelligence abilities suggests cognitive processing beyond what is required in standard linguistic tests (e.g., the ASL-SRT, which did not correlate the KBIT-2). Since more proficient signers performed better on ASPCT, we suggest that ASPCT assesses linguistic abilities related to comprehending classifier constructions. This hypothesis is also supported by the finding that participants with higher accuracy on ASPCT were marginally more likely to reproduce sentences from the sign model’s perspective in the ASL-SRT. This result suggests that signers who routinely adopt the signer’s perspective – even when it is not required by the situation or discourse context – may be better able to understand viewpoint dependent spatial classifier descriptions.

Finally, we observed a marginal effect of gender on ASPCT accuracy ($p = .056$), with males scoring higher than females. This result is in accordance with evidence indicating that males tend to perform better on spatial tasks (e.g., Voyer, Voyer, & Bryden, 1995) or better on tasks that are perceived to be spatial (Tarampi et al., 2016). Interestingly, there were no gender effects for the ASL-SRT, neither for the full ASL-SRT nor for the “perspective-dependent” subset of items ($t(36) = -.64$, $p = .52$; $t(36) = -.87$, $p = .39$). This pattern suggests that the (marginal) gender effect observed for ASPCT may arise from nonlinguistic spatial aspects of the task or from the perceived spatial character of the test (Tarampi et al., 2016).

Conclusion

Locative classifier constructions in ASL encode a variety of information quickly (e.g., the relative position, distance, and orientation of objects) by allowing the hands to directly map on to these features of the world. When interlocutors share visual access to the referents, there is a direct correspondence between the objects the addressee sees and the arrangement of hands. Without shared visual access, the addressee must accommodate the signer’s perspective via some kind of mental transformation. The subjective experience of this transformation may seem instantaneous, but the data presented here suggest mental transformations take time and impact accuracy in timed settings. Future research might further examine the relationship between viewing angle and response time in this mental transformation process, as has been done for both perspective-taking (Kessler & Thomson, 2010) and mental rotation (Zacks, 2008). The ASL Spatial Perspective Comprehension Test fills a gap in the literature with respect to assessment of perspective-dependent linguistic constructions in ASL, and thus may be utilized in future research as a metric of spatial abilities in ASL. A video version of ASPCT is available from the authors upon request.

Notes

1. There was no difference in performance on ASPCT between the native signers and the early-exposed signers for either accuracy, $t(36) = .54$, $p = .77$, or reaction time, $t(36) = -1.2$, $p = .14$.

2. Pilot testing revealed that seven seconds was an optimal time window for this type of task (avoiding both ceiling effects and poor performance/frustration).

Funding

This work was supported by National Institutes of Health [R01 DC010997 to K.E.]. The authors would like express gratitude for the contributions of our participants, our stimulus model, Cindy Farnady, as well as our research assistant, Nina Sousa.

Conflicts of interest

No conflicts of interest were reported.

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