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Hands Show Where Things Are:
The Close Similarity Between Sign and Natural Space

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Many of the signs produced across sign languages are iconic, in the sense that they resemble the concepts they represent. We examined whether location, one of basic sign parameters along with handshape and movement, is systematically used for purposes of iconicity. Our findings revealed a mapping of vertical sign space that is exploited in its entirety for encoding typical locations in natural space. In all of the twenty sign languages we analyzed, signs were more likely to have high locations with concepts typically occurring in high vs. low regions of natural space (e.g., *cloud* vs. *root*). Furthermore, the height of signs produced to identify a visual object varied depending on object position (e.g., it was higher for *basketball* in the basket than *basketball* on the floor). It thus appears that signing space is permeable to semantic and episodic features, and iconicity plays a crucial role in making signing space so adaptable.

Ever since the first descriptions of sign languages appeared in the 18th century (e.g., de l'Épée, 1776), it has been emphasized that many signs resemble the concepts they represent – to characterize it in linguistic terms, there is a conspicuous presence of iconic signs. Extensive linguistic research conducted in the last five decades has revealed that iconic signs are embedded in a rich linguistic system that determines the form with which signs appear in a language. This led researchers to recognize the close similarity of sign and spoken languages. In sign languages, there is a phonology underlying the combination of linguistic parameters such as handshape, movement, and location, similar to how there is a phonology governing phoneme sequencing in spoken languages (Brentari, 1998; Klima, & Bellugi, 1979; Liddell & Johnson, 1989; Sandler & Lillo-Martin, 2006; Stokoe, 1960). Importantly, phonology enables sign languages to reach the arbitrariness found in any other natural language. Linguistic research has also shed light on the iconicity characterizing signs. It was realized that phonology constrains how iconicity could be represented in a sign, and that arbitrariness could also limit iconicity (Aronoff, Meir, & Sandler, 2005; Demey & van der Kooij, 2008; Dingemanse, Blasi, Lupyan, Christiansen, & Monaghan, 2015; Emmorey, 2014; Meir, 2010; Taub, 2001). Evidence revealing a conflicting interplay between iconicity and arbitrariness emerged from studies that tracked the history of sign languages (Frishberg, 1975) or cross-generational change (Brentari, Coppola, Mazzoni, & Goldin-Meadow, 2012; Fontana, Corazza, Braem, & Volterra, 2015; Kegl, Senghas, & Coppola, 1999; Meir & Sandler, 2008; Sandler, Meir, Padden, & Aronoff, 2005). The evolution of sign languages over historical time resulted in the increasing consolidation of arbitrariness and the erosion of iconicity. More recently, psycholinguistic research has shed light on the interplay between iconicity and sign processing. Although it remains unclear if iconicity plays a role in sign acquisition or specific cognitive domains (e.g., memory; Bellugi, Klima, &

Siple, 1975; Perniss, Thompson, & Vigliocco, 2010), data from psycholinguistic research showed that iconicity facilitates the production (Baus & Costa, 2015; Navarrete, Peressotti, Lerose, & Miozzo, 2017; Pretato, Peressotti, Bertone, & Navarrete, 2018) and possibly also the comprehension of signs (Vinson, Thompson, Skinner, & Vigliocco, 2015). These processing advantages might in turn contribute to consolidating and protecting the persistence of iconic signs in the language.

Once iconicity is viewed from the perspective of phonology, it is clear that the impact of phonology is not limited to determining the form with which iconic signs appear in a language, extending instead to conceptual features. It is in fact only those features that can be transparently represented by means of handshape, movement, and location that are expressed iconically (Meir, 2010; Pietrandrea, 2002; Taub, 2001). For example, if the eyes represent a location in the sign language, concepts related to seeing produced at this location make it explicit the relation to vision. The constraints phonology imposes on concept representability make some features privileged candidates for embodiment into iconic signs. This embodiment is seen with object shape, which is strongly related to handshape, or object movement and the actions we perform with objects, which are typically associated with movement (Cates, Gutiérrez, Hafer, Barrett, & Corina, 2013). In the present study, we investigated whether object location is systematically encoded in sign languages.

Some objects are typically in predictable places: clouds in the sky, books on shelves, hydrants along the street. It is naturally desirable to know where objects occur, as this information would help to recognize, find, or grasp them. Further advantages possibly arise with signs. Embodying information about object location into signs would enrich iconicity, and this could potentially facilitate the production and recognition of signs. Signs are produced within the space in front of the signer, extending vertically from the waist to above the head, horizontally as far as the arms stretch. They are thus localized with reference to **three body-centered axes** – vertical, horizontal, and **back-to-front** – as well as to specific body parts (e.g., arm, head) (Brentari, 1998; Liddell & Johnson, 1989; Sandler, 1989; Stokoe, 1960; Taub, 2001). The organization of sign space provides a natural backdrop for reproducing object locations varying in natural space along vertical or horizontal axes.

Concepts like *cloud* or *root* usually appear in given positions of the vertical visual space and several studies investigated to what extent this information is automatically activated by linguistic information (e.g., Bergen, Lindsay, Matlock, & Narayanan, 2007; Stanfield & Zwaan, 2001; Glenberg & Kaschak, 2002). To explore this issue, a few studies focused on the spatial compatibility effects. It was showed that words such as *cloud* or *root* facilitated hand movement and eye movement toward a location consistent with their typical positions (Dudschig, Souman, Lachmair, de la Vega, & Kaup, 2013; Lachmair, Dudschig, De Filippis, de la Vega, & Kaup, 2011; Thornton, Loetscher, Yates, & Nicholls, 2013). For example, when the decision of whether written words corresponded to words existing in the language was made by looking upward or downward, responses were faster when the response positions coincided with the natural localization of the word referent (e.g., *cloud*-up; Dudschig et al., 2013). These results were replicated with valence concepts (e.g., *love*, *hate*) and religious concepts (e.g., *god*, *devil*), thus suggesting that spatial compatibility effects relate not only to natural space but also to metaphorical space where abstract concepts can be figuratively localized according to culturally shared spatial co-ordinates (Chasteen, Burdzy, & Pratt, 2010). In this way, the localization of *love* in the uppermost region of space stemmed from culturally based associations between up and positive emotions and moral values (Lakoff & Johnson, 1980). Although questions remain about the nature of spatial compatibility effects (Barsalou, 2016; Mahon & Hickok, 2016) and their occurrence (de la Vega, Dudschig, De Filippis, Lachmair, & Kaup, 2013; Papesh, 2015; Petrova, Navarrete, Suitner, Sulpizio, Reynolds, Peressotti, 2018; Rommers, Meyer, & Huettig, 2013), these effects reveal that information about object position in vertical space can be readily activated during reading and, more generally, a sensitivity to object position in vertical space. The question we addressed in the present study is whether the salience of object positions in natural space would affect sign location and if this parameter can therefore be used iconically to represent those positions. This question has ramification not only for mapping how object localization is encoded in individual languages or cross-linguistically, but also for understanding how signers embody object localization through signs. One of these two facets of the question is more descriptive in nature, while the other relates to signers' use of the language and the extent to which signers exploit opportunities provided by the language.

Although natural vertical locations would, in theory, map onto sign space, other features of sign languages could severely limit the extent of such mapping. Attention should be given in this respect to two types of evidence. A first relevant fact is that signs can be positioned with respect to body parts. An example is provided by the sign *eating* that is seemingly universally produced around the mouth (Meir, Padden, Aronoff, & Sandler, 2007). In this case, a concept that might not be strongly associated with a high natural position has a sign occurring high in sign space. The priority could be to associate signs with body parts transparently expressing key conceptual features (e.g., mouth → *eating*) rather than having object natural positions embodied into sign locations. Another type of relevant evidence relates to historical data indicating that, as the language evolves, signs in the periphery of the sign space shift toward more central locations (Frishberg, 1975), a change probably dictated by the pressure to improve fluency and articulation.

Indirect support of this hypothesis comes from experimental data showing significant lowering of signs occurring in high sign space when production rate increases (Liddell & Johnson, 1989; Lucas, Bayley, Rose, & Wulf, 2002; Tyrone & Mauk, 2010), as compacting sign space would better satisfy increasing biomechanical constraints of the articulators. In the end, a mapping in vertical space between natural and sign positions could still arise against tempering tendencies that drive toward central locations and anchoring signs to specific body parts.

Our investigation included two studies. Study 1 was descriptive and comprised three parts. In Study 1a, we examined concepts with typical locations in high vs. low regions of natural space (*cloud*, *root*) that previous studies have demonstrated to induce spatial compatibility effects. We analyzed whether the sign corresponding to these concepts in twenty languages are produced in the high region of sign space. We anticipated that this would occur especially with signs referring to concepts with high typical locations, if a mapping exists between natural and sign space. More accurate measurements of sign positions were used in Study 1b to compare signs corresponding to concepts with high vs. low typical locations. Finally, in Study 1c we investigated whether the mapping between natural and sign locations varies continuously along the vertical axis, so that a more systematic and precise encoding of natural locations is possible within sign space. Study 2 was experimental and focused on the use of signs to specify the height of distinct locations in which objects appear, as in the case of the basketball that can be seen on the floor, a bench and a shelf, or in the air if thrown. Participants in Study 2 were instructed to produce the signs of familiar objects such as *basketball* presented in contextually high or low spatial positions (*basketball* on the floor; *basketball* in the basket). We examined if sign location varied depending on object contextual position, even in a signing task lacking explicit demands to specify object positions. We expected an implicit encoding of object positions to result in higher (lower) sign positions for objects presented in upper (lower) regions of space.

Study 1a: Comparison across twenty sign languages

Materials

We examined English words referring to concepts with an upward spatial association (*up concepts*; *n* = 90) or a downward spatial association (*down concepts*; *n* = 68). All the words had induced spatial compatibility effects in prior studies that investigated such effects (Dudschig, de la Vega, De Filippis, & Kaup, 2014; Estes, Verges, & Adelman, 2015; Gozli, Chasteen, & Pratt, 2013; Lebois, Wilson-Mendenhall, & Barsalou, 2015; Meteyard & Vigliocco, 2009; Thornton et al., 2013; Verges & Duffy 2009). Furthermore, in pre-tests conducted in those studies, participants rated the extent to which the concepts were typically associated with upward or downward locations (e.g., using a 1-7 point scale). Each up concept received a higher mean rating relative to down concepts. As determined in those studies, the words related to concrete objects (e.g., *roof*, *worm*), abstract concepts (e.g., *passion*, *guilt*) or verbs (e.g., *to jump*, *to dig*). None of the words referred to body parts, which cross-linguistically are generally represented by indexical signs involving pointing to the corresponding body part (Padden, 2010).

Signs were retrieved from *Spread the sign* (https://www.spreadthesign.com/us/), a multi-lingual web archive developed by the European Sign Language Centre. Signs were searched by entering an English word and selecting one of the sign languages listed at the time the search was conducted (2017). Signs were shown on the website as produced by a proficient user of the language facing the camera, in their entirety, and in clear view. We excluded compound signs and signs produced using fingerspelling. Compound signs were excluded because their constituents could refer to up and down concepts, respectively; the Turkish sign *root* is an example: its first constituent is *tree* (an up concept), whereas its second constituent is *root* (a down concept). The place constraint introduced by Battison (1974), stating that a morpheme may have only one place of articulation, was generally followed to identify compounds. To have a sufficiently large number of analyzable signs from each language, we only considered those languages for which signs were found for at least 50% of the words we searched. This criterion led to exclusion of signs from four languages (Bulgarian, Greek, Indian, and Japanese). [Footnote 1] We analyzed the signs from the twenty languages listed in Table 1. Across languages signs were found, on average, for 84% of the words (range: 50-97%), with comparable rates for up and down concepts (84% and 82%). The complete list of signs analyzed in Study 1a is shown in Appendix A.

Procedure

Videos of the signs were downloaded from the website and analyzed by two of the authors (MM and MV). These two raters identified the frame in which one of the hands reached the highest point. A horizontal line extending along the signer's shoulders was superimposed on the video frame, and was used to determine whether the hand's highest point was above the shoulders. Shoulders were chosen as baseline because, first, they can be easily and consistently identified, and second, the space above them corresponds to a relatively high region in signing space. The two raters independently scored the highest point as above or below the signer's shoulders, and agreement was consistently found for initially contrasting scores. We could not reliably determine whether the highest point of 7% of the signs occurred above or below shoulder line; these signs were excluded from analyses. The signs we examined referred to 1438 up concepts and 984 low concepts, respectively.

Results

Analyses in Study 1a focused on the signs with the highest point above signer's shoulders. In an aggregated analysis we examined the signs from all of the twenty languages. As illustrated in Figure 1, signs were more likely to have highest points above the signer's shoulders when associated with up concepts (85%, 1223/1438) compared to those referring to down concepts (47%, 462/984; $\chi^2(1) = 401.05$, $p < .0001$). In a by-item analysis we examined the mean number of signs corresponding to a given concept produced, in the twenty languages, with the highest point above the signer's shoulders. High points occurred above the signer's shoulders more often with signs corresponding to up concepts ($t(156) = 10.6$, $p < .0001$), a result showing that differences between up and down concepts generalized across items. Aggregated and by-item analyses were replicated with concrete objects, abstract concepts, and verbs. Preferences for producing up-concepts above the signer's shoulders appeared in aggregated analyses with signs representing concrete objects (95% vs. 34%; $\chi^2(1) = 467.39$, $p < .0001$), abstract concepts (76% vs. 54%; $\chi^2(1) = 42.29$, $p < .0001$), and verbs (77% vs. 59%; $\chi^2(1) = 22.06$, $p < .0001$). Similar preferences appeared in by-item analyses (concrete objects: $t(67) = 14.6$, $p < .0001$; abstract concepts: $t(47) = 3.8$, $p = .0004$; verbs: $t(38) = 2.1$, $p < .05$).

To assess the cross-linguistic robustness of these findings, we examined the corpus of signs available in each language. As illustrated in Figure 2A, signs representing up concepts were preferentially produced above the signer's shoulders in each language ($p < .05$; p Bonferroni-corrected for the 20 languages tested).

Figure 2B shows that the rate with which signs extended above the signer's shoulders varied across languages, occurring, for example, quite frequently in Portuguese Sign Language (82%) or Brazilian Sign Language (91%), but far less so in Austrian Sign Language (50%) or Czech Sign Language (53%). This result implies that signs tend to cluster within regions in the vertical sign space that might differ from one language to another. Figure 2C shows the percentage of signs corresponding to up and down concepts that were produced above the shoulder across the various languages. The significant correlation found between these signs cross-linguistically ($r = .81$, $p < .0001$; Fig. 2C) indicates that signs associated with up and down concepts are similarly affected by the language-specific preferences in the use of the signing space.

If the correspondence between locations in natural and sign space holds cross-linguistically, it should appear regardless of whether or not the languages are related. Testing this prediction is unfortunately difficult, given our limited knowledge of the history and relatedness of sign languages. Based on sign similarity data, Bickford (2005) identified two of the sign languages we examined – Russian and Ukrainian – as related and members of the same family. Out of the signs analyzed in both of these languages, 61% (46/75) consistently occurred above or below the signer's shoulders. A comparable rate (54%, 58/107; $\chi^2 < 1$) was found between Russian Sign Language and American Sign Language (ASL), two unrelated languages according to Bickford (2005). Although based on a very small number of comparisons, these results are in line with the prediction and together with the other findings of Study 1a show a close mapping between sign and natural vertical space.

Study 1b: Distance measures

Study 1b improved on Study 1a in two ways. First, we obtained a more precise measurement of sign positions in vertical space, as we determined the distance (in pixels) of sign highest and lowest points from baseline (the signer's shoulders). Second, material selection was better controlled. Native signers confirmed that the signs from ASL and Italian Sign Language (ISL; *Lingua Italiana dei Segni*) analyzed in Study 1b were not compounds – as discussed above, compound signs would introduce a confound.

Materials and Procedure

Up and down concepts were selected following the procedure described in Study 1a. It was further inspected that the ASL and ISL signs corresponding to these concepts were not compounds and did not have embedded fingerspelling. A native signer for each language, unaware of the study purposes, produced all the signs in that language. The signer was presented with a written list of the English words (or their Italian translations) and was instructed to produce the corresponding signs in the same way as s/he would sign to friends or in any other familiar circumstance. The signs referring to up and down concepts, respectively, were 96 and 96 in ASL, and 115 and 97 in ISL. The difference in the number of signs analyzed in each language is due to the fact that we excluded compound signs and signs including fingerspelling, and that one sign could translate more than one word from the list we compiled. The complete sign list is presented in Appendix B.

Baseline location was constant across signs as signers stood in the same position behind the camera and at a distance of 15 cm in front of a wall. Two dots placed on the wall at the height of the signer's shoulders (see Fig. 3) served as points of reference for the shoulder line. Similar to Study 1a, we identified the frame showing the highest and lowest point of each sign. The hand part coinciding with such points could vary from sign to sign – e.g., the wrist in one sign, the thumb tip in another sign. A bracelet on the signer's wrist was used to consistently identify this location. Using the dots behind the signer in the video frame as end-points, we drew a line at shoulder height that served as baseline for measuring the distance of sign highest and lowest points, as illustrated in Figure 3. Ballistic movements that occurred before and after the sign itself were not considered in the analyses.

Results

As shown in Figure 4, the ASL and ISL signs corresponding to up concepts had their highest points typically occurring above the signer's shoulders, contrasting with the ASL and ISL signs referring to down concepts, for which the highest points were often below the signer's shoulders. Moreover, the lowest points were further below the signer's shoulders with ASL and ISL for signs representing down concepts relative to up concepts. The marked differences between these signs were confirmed by the results of an ANOVA we conducted with Concept (up vs. down) and Point (highest vs. lowest) as variables. The main effect of Concept was significant in both languages (ASL: $F(1, 191) = 55.77$, $p < .0001$; ISL: $F(1, 211) = 69.88$, $p < .0001$). The interaction was significant in ISL ($F(1, 210) = 7.65$, $p < .01$) and borderline significant in ASL ($F(1, 190) = 3.18$, $p = .07$). Post-hoc analyses showed highly significant differences ($p < .0001$) between signs corresponding to up vs. down concepts for the highest points as well as for the lowest ones in both languages. As illustrated in Figure 4, the interaction is explained by the fact that the difference between signs corresponding to up and down concepts is larger with the highest points as compared to the lowest points.

To better contextualize the location differences found between up and down concepts, we determined the rate in which the highest points occurred above approximate body landmarks (shoulder, mouth, eyes, head top). As illustrated in Figure 5, the signs referring to up concepts were consistently produced in these upper regions of the signing space more often that the signs corresponding to down concepts.

We calculated the extension with which the sign was produced in vertical space by subtracting the lowest points from the highest points. The difference in extension between signs representing up and down concepts was significant in ISL ($t(210) = 3.22$, $p = .001$) and approached significance in ASL ($t(190) = 1.78$, $p = .07$). In both languages, the difference reflected the greater vertical extension for signs expressing up concepts.

Further analyses were conducted to assess the reliability of the data obtained in Study 1a that were based on cruder measurements and less accurately controlled materials than those obtained in Study 1b. Signs for the same 225 concepts were available in both studies in ASL as well as in ISL. As in Study 1a, we determined if the sample of signs from Study 1b were produced above the signer's shoulders. Of the signs produced above the shoulder line in Study 1a, 97% were produced in the same location in Study 1b. The robust cross-study consistency demonstrated by these results strengthens our confidence on the results from Study 1a. Importantly, the data from both studies showed concordances between the sign vertical positions and natural vertical space.

Study 1c: Rating-based analyses

The data presented above revealed a dichotomization of the vertical space, such that signs corresponding to up concepts tended to occur in higher regions of the sign space, whereas the opposite distribution was found for those signs referring to down concepts. In Study 1c, we examined whether sign location is exploited across languages more systematically and with a finer degree of granularity. To this end, we extended our investigation to include concepts typically occupying the middle portion of the natural vertical space, in between high and low ends, such as *table* or *pen*. Furthermore, we obtained a gradual mapping of concepts' locations in natural vertical space and explored whether this mapping was mirrored by sign vertical locations.

Materials and Procedure

The experiments from which we drew the concepts examined in the first two studies (Dudschig et al., 2014; Estes et al., 2015; Gozli et al., 2013; Lebois et al., 2015; Meteyard & Vigliocco, 2009; Thornton et al., 2013; Verges & Duffy 2009) also identified concepts that do not typically occur in high or low regions of natural space, but instead lie in between these regions. Unlike up and down concepts, these 'middle concepts' did not consistently induce spatial compatibility effects. These 'middle concepts' were analyzed in Study 1c, along with the up and down concepts from Study 1b. We collected ratings concerning concept typical location in the natural vertical space, using a 1-7 point scale, where 1 and 7 indicated the lowest and highest positions, respectively. The signs for Study 1c (listed in Appendix B) were produced by the same ASL and ISL signers who provided the signs for Study 1b. To account for possible cultural differences, the raters of one group were 10 English speakers living in the USA, whereas the raters of another group were 10 Italian speakers living in Italy. Raters were presented with the same word list given to the signers. The procedure for measuring the highest and lowest points of the signs was the same as the one described in Study 1b. The number of signs analyzed in ASL and ISL was 257 and 362, respectively.

Results

Significant correlations were found between the ratings and each of the vertical sign space parameters (highest point, lowest point, and vertical extension), both in ASL (Fig. 6) and ISL (Fig. 7). As summarized in Table 2, further correlations were carried out with the signs representing specific types of concepts: concrete objects, abstract concepts, and verbs. Across languages and vertical sign space parameters, correlations were consistently significant with signs referring to concrete objects. Results also showed that correlations were especially robust for the highest points.

Significant correlations were found between highest and lowest points, both in ASL ($r = .42$, $p < .0001$) and ISL ($r = .47$, $p < .0001$). Furthermore, the highest and lowest points turned out to be significantly correlated in both languages for signs corresponding to up, down or middle concepts ($rs = .31-.54$, $ps > 001$). These results indicate that the two points are to a certain degree related, so that a sign with a very low lowest point has a highest point that is not very high, and vice versa – a sign with a very high highest point has a lowest point that is not very low.

Overall, the results of Study 1c reveal that the vertical sign space can be used in its whole extension to encode the positions with which concepts are typically associated within natural space. It is also worth mentioning that the 131 signs representing the same concepts in ASL and ISL showed a strong relationship, as demonstrated by the robust correlations ($p < .001$) between their highest points ($r = .70$), lowest points ($r = .44$), and vertical extension ($r = .42$).

Study 2: Naming-by-signing

A number of objects appear in spatial locations varying in height, as when a *basketball* is on the floor as compared to in the basket, or the *moon* is low on the horizon relative to high in the sky. Just as when speakers name a visually presented single object, signers do not have to specify the object position when signing that object, and indeed the picture of the basketball or the moon could be signed in the same way despite variations in the spatial position of the pictured object. In **signing the picture name**, however, it is in theory possible to encode the object position on vertical space by correspondingly varying the height of the sign – at least, if changes in sign locations do not compromise the proper execution of the sign, and consequently its comprehension. In Study 2, we explored if sign locations vary for height as a function of object position on vertical space, so that, for example, the sign *basketball* would appear at a lower location when referring to a *basketball* on the floor as compared to in the basket. Figure 8 provides an example of the scenes created in Study 2 to show objects in contextually high or low spatial positions. ISL signers were instructed to sign a specific object (the target) in a scene. Participants could easily identify the target, as it was the only object in the scene that next appeared alone. Instructions emphasized signing the target using a single sign.

Crucially, the target's position on the computer screen remained the same – only its contextual location changed. We examined if the three features we measured for each sign (highest and lowest points and vertical extension) varied depending on the context in which targets appeared.

Participants

The ten deaf ISL signers (6 female and 4 male) who participated in Study 2 varied in age (range = 21-62 years; mean = 46.6, SD = 12.5). Eight participants, deaf from birth, acquired ISL from their deaf parents; two participants became deaf after birth and learned ISL when 10 and 12 years old, respectively. All participants used ISL as their primary language.

Materials and Procedure

The 37 targets selected for Study 2 satisfied criteria concerning the depicted objects and their corresponding ISL signs. We chose objects that could naturally appear in places differing in height, for example the *basketball* that can be on the court floor or thrown into the basket. Furthermore, we excluded ISL signs produced by contact with specific positions on the head, shoulder or chest, a feature limiting possible variations in sign locations. The two scenes drawn for each target provided the context for setting the targets in low or high places, as shown in the example in Figure 8 (for the list of targets and scenes, see Appendix C). As in Study 1c, we collected ratings from 10 Italian speakers concerning concepts' typical positions in the natural vertical space, using a 1-7 point scale (1 = lowest position; 7 = highest positions; mean = 3.6, sd = 1.3). The ratings, which are reported in Appendix C, were distributed along the whole range.

Each trial began with the fixation point that was shown for 200 ms and followed by the presentation of a scene for 2.5 s, after which only the target appeared for 1 s. Participants started the next trial by pressing the space bar. The target appeared on the same screen position in the scene and alone. Targets were presented in different orders, randomized under the constraint that they could not be repeated within the next 5 trials. Instructions required participants to sign the object that appeared alone and emphasized that the task consisted in producing one sign only – i.e., the sign corresponding to the target.

The screen on which the stimuli were shown was positioned at a distance of about 50 cm from the participant. The procedure for recording and measuring the highest and lowest sign positions was modelled after that used in Study 1b. Participants faced a camera positioned at a distance of 2 m and the bracelet they wore on each wrist served to determine sign height. Highest and lowest sign positions were measured (in pixels) relative to the position of the right bracelet while participants stood with the arms extended alongside the body. Although the baseline varied across participants, the same baseline was used for all the signs produced by an individual signer. Importantly, we analyzed the same 'component' of the two signs a participant produced for the target. For example, with the ISL sign *bicycle*, which is produced by repeatedly circling the two hands in a way that resembles pedaling, we considered the first of these circling movements. Ballistic movements recorded before and after the sign itself were not considered in the analyses.

The means of the highest and the lowest points were analyzed using ANOVAs and the variables Point (Highest and Lowest) and Context (Up and Down). The measures obtained for the highest points or the lowest points were averaged across items in analyses based on participants' responses; measures were averaged across participants in analyses based on the items.

Results

Results were based on 630 of the 740 signs we tested, as 110 signs were omitted because they were unknown (n = 4) or involved contact with specific face locations (n = 4), different signs were used to identify the pictured target (n = 50), and the target was missed (n = 52; only 26 targets were actually missed, but because we analyzed two responses for each target, we also excluded the sign produced for that target). **Participants never produced deixes or other signs that described the scene or the target's position within the sign. That is, participants consistently produced a single sign, as instructed.**

The analysis based on participants' means revealed a significant effect of Context ($F(1, 9) = 35.64$, $p = .002$), a result replicated in the analysis based on targets' means ($F(1, 36) = 43.91$, $p < .001$). Both results were explained by the higher locations of the signs used to articulate targets that appeared in higher contextual positions, as showed in Figure 9. The averaged difference, equal to 49 pixels, corresponded to a visual angle of 1º. As suggested by the lack of significance of Point ($Fs < 1$) and Context x Point interaction ($Fs < 1$), comparable differences in sign locations were found for the highest and lowest points. Of note, the difference appeared, numerically, with each participant, a finding demonstrating the pervasiveness of the contextual effect. Contrasting with the findings with the highest and lowest points, the signs articulated in response to targets appearing in different spatial positions had very similar vertical extensions, covering an average of 198 and 200 pixels, respectively. The comparable vertical extensions arose because the whole sign was shifted upward or downward as target's spatial position varied.

We examined if sign repetition was at least in part responsible for the contextual effect we observed with the highest and lowest points of signs. Two findings make repetition potentially relevant in this context. First, responses become faster with repetition and, second, signs tend to occur in a more reduced space as signing speed increases (Liddell & Johnson, 1989; Lucas et al., 2002; Tyrone & Mauk, 2010). It is thus possible that the location differences we observed resulted from compacting the signing space the second time the sign was produced. To assess the effect of repeated sign production, signs' highest and lowest points were averaged either across items or participants and entered in repeated measure ANOVAs with Sign Production (First vs. Second) and Point (Highest vs. Lowest) as variables. Neither the effect of Sign Production nor the interaction were significant ($Fs < 1$), thus confirming that the observed difference related to target contextual position. [Footnote 2]

General Discussion

Our results revealed a pervasive encoding of object positions in sign language with effects that were not limited to shaping the lexical forms existing in a language, but instead extended to language use. Close similarities between typical object positions in natural vertical space and the locations of their corresponding signs in vertical sign space were found in each of the twenty sign languages we examined (Fig. 2B). There were obvious limitations in our cross-linguistic investigation, primarily that we could not assess the reliability with which signs translated key English words and that sign location was based on crude binary scores (above/below the signer's shoulders). Nevertheless, these cross-linguistic results were replicated with materials selected more accurately and sign locations measured more precisely (Study 1b), in addition to being confirmed by the analyses of the signs that multiple signers produced in the context of the more ecologically valid task of signing the picture names (see Footnote 2). Altogether, our results provided reasonably strong indications that similarities between natural and signing vertical space represent a universal feature of sign languages. Our results also revealed a systematic mapping of vertical sign space that is exploited in its entirety for encoding typical locations in natural space. In this way, signs mark locations across all regions of natural space – from downward to upward – as well as within each of these regions. Furthermore, we found that correspondences with vertical sign locations hold not only for concrete objects but also for abstract concepts (*comfort, failure*). Therefore, vertical sign space can also be used metaphorically. It is not only at the lexical level, however, that we found evidence that signs encompass object positions; by showing that sign location varies as a function of the spatial position of the signed object, our results demonstrate that language use is similarly adaptable to encoding spatial positions. As discussed below, the various aspects of our results are relevant for issues related to sign location and sign iconicity.

The organization of sign space

The result consistently found in our investigation that sign highest and lowest points are equally related to the referent's location in natural space, implies that both of those points carry information relevant for sign meaning. Furthermore, the correlation we found between the locations of these points indicates that a sign tends to be produced within a specific region of the sign space. In this way, for example, both points have lower locations in the ASL sign *root* than the corresponding points of the ASL sign *cloud.* Limiting sign production within a certain region of sign space (e.g., upward) would naturally make the sign equivalence with natural space more transparent. However, by reducing the extent of the space within which the sign unfolds, a movement minimization occurs that is desirable from a biomechanical perspective (Tyrone & Mauk, 2010). In essence, pressure stemming both from semantics and movement constraints could potentially contribute to sign location in the vertical space.

By identifying the highest and lowest points of a sign we could determine its extension in vertical space, which we found to vary consistently as a function of the typical locations of the referent. This finding probably reflects differences between up and down concepts, specifically the greater extension of signs corresponding to up concepts (see Study 1b). Our investigation thus reveals that sign vertical extension is another spatial feature contributing to sign iconicity, which in this capacity would affect sign location. It should be emphasized that sign highest and lowest points, and relatedly vertical extension, were explored only in two languages (ASL and ISL). Although our cross-language investigation was based on a large set of signs and led to converging findings, further research is needed to establish whether sign highest and lowest points and vertical extension are generally exploited for purposes of iconicity across sign languages.

Our results, which revealed a continuous distribution of sign locations along the vertical axis in sign production, paralleled the findings in sign comprehension that demonstrated a similar organization of the signing space (Emmorey McCullough, & Brentari, 2003). From a cognitive (and computational) perspective, a continuous distribution of locations could in theory be represented in two distinct ways differing as to whether the body or body parts are used as a reference. According to the first account, sign locations are defined with respect to a vertical axis centered on the body, extending from the lowest to the uppermost points of the sign space. As locations vary continuously along this body-centered axis, they can be encoded with equal degree of precision on vertical space. Alternatively, locations are determined with reference to body parts such as torso, hand, arm, or head and, in order to reach a greater degree of granularity, they can be further specified within each region centered on a body part – e.g., by distinguishing high vs. middle vs. low locations. This account echoes previous linguistic theories that provided phonologically based descriptions of signs (e.g., Sandler & Lillo-

Martin, 2006). Our data are compatible with both accounts and do not allow us to discriminate between them.

Our investigation, however, shed light on another relevant aspect of the encoding of sign position. The finding in Study 2 that signs encode the arbitrary positions of visual objects indicates that location is not an invariable parameter of the sign, but one that is flexible and adaptable. There are other examples of sign displacements, one is found in ASL with whispering (Emmorey, 2002). Signs normally articulated on the face or the body appear, in whispering, in locations (e.g., below the chest) that make them less visible. It should be noted that the displacement enacted in whispering has clear communicative purposes. Being limited to the production side of signing, our investigation does not inform us on whether changes in sign location associated with object positions has an analogous communicative function. These changes, which were in the magnitude of 1º of visual angle, are certainly detectable, but further research is needed to establish whether they provide meaningful clues for understanding object position.

Each feature of sign location we examined in Study 1a (highest and lowest points, vertical extension) was consistently related to the natural location of concrete objects, the type of signs most extensively represented in our corpora analyses. Results were equally robust in Study 1a for signs referring to abstract concepts (e.g., *passion*, *guilt*) or verbs (e.g., *to jump*, *to decrease*) only with the highest point. It is possible that the specificity of the highest point emerged in our investigation reflects something distinct about this feature, for example that the uppermost region of the signing space provides a better opportunity to encode natural locations. However, the specificity of the highest sign could in part stem from our choice of the shoulder line as baseline – the larger space above (as opposed to below) the shoulders made the highest points, which typically occur above the shoulders, a more sensitive measure. We should also point out that because signs referring to verbs and abstract concepts were less represented in the corpus analyzed in Study 1, their data need to be interpreted cautiously.

An unexpected finding of our investigation was that signs occur in the high space above the signer's shoulders in different rates across languages (see Fig. 2B). Variation was quite substantial, ranging from 50% in Austrian Sign Language and 53% in Czech Sign Language to 82% in Portuguese Sign Language and 91% in Brazilian Sign Language. This finding reveals that vertical space is used asymmetrically across sign languages, with signs clustering preferentially within specific regions of vertical space in each language. Since our finding was based on a relatively small number of signs, caution should be used in drawing inferences about the sign distribution in a whole language. Nevertheless, as this finding relates to uppermost sign locations, it informs us about the upward boundary of sign space – by itself, it is a suitable data point for gauging the sign distribution in the vertical space in a language. The cross-linguistic variation of the phonological parameter of sign location suggested by our data is reminiscent of instances of phonological variations existing cross-linguistically in spoken languages, a primary example of which involves vowel space (Ladefoged & Maddieson, 1996). In this respect, phonology in spoken and sign languages exhibits a comparable degree of arbitrariness from which cross-linguistic variability may arise. However, the cross-linguistic variability shown by sign locations in vertical space stands in sharp contrast to the cross-linguistic consistency that signs referring to up and down concepts regularly occur in the high and low regions of sign space, respectively. The appearance of these contrasting results reflects the role arbitrariness and iconicity play in shaping the organization of sign space, with the first setting the range of sign distribution in vertical space, and the latter affecting the location of signs with iconic significance within a language-specific region. In this way, differences between the locations of signs referring to up and down concepts should arise in each language.

Sign iconicity

Our data revealed that it is not just handshape and movement that are co-opted to represent a referent iconically; location seems to have a similar function. Each of the fundamental parameters in sign phonology add to the multifaceted nature of iconicity, each contributing primarily to represent distinct types of features: handshape characterizes object forms, movement relates to object motion and action toward the object, and location denotes object position. By showing a close association between sign location and iconicity, our results help in defining how iconicity is implemented in sign language, in addition to strengthening the notion that iconicity is multifaceted (Aronoff et al., 2005; Brentari et al., 2012; Cates et al., 2013; Emmorey, 2014; Klima & Bellugi, 1979; Meir et al., 2007; Sandler & Lillo-Martin, 2006; Taub, 2001). It is also worth noting, however, that location establishes a different type of relationship with iconicity than handshape and movement. Diverse object features can be transparently expressed by handshape, including shape and size or mimicking object parts. There are plenty of cross-linguistic examples proving this point; one is provided by the handshape of the sign *mouse* that relates to a mouse's nose in ASL, to a mouse's body in ISL, and to a mouse's ears in Icelandic Sign Language. As these examples show, there is a certain degree of arbitrariness in the way handshape conveys iconicity. Although to a lesser degree, arbitrariness exists also with movement, as this parameter can be associated either with the motion of an object or the action one makes with the object. In contrast, the relationship between iconicity and location is more univocal and transparent, at least with the typical position of an object in natural vertical space. Because these typical positions can only map onto a specific position in sign space, arbitrariness is reduced to a binary choice with sign location – i.e., whether or not location corresponds to the object position in natural space.

The iconicity of sign location is not restricted to distinguishing between up and down concepts, but it is also used to mark positions varying across the entire extension of vertical natural space or arbitrary changes in the height of object positions. Thus, locations with iconic reference are not only those of *airplane*, an up concept, or *root*, a down concept, but also of *table* and *pencil*. Furthermore, the locations of the signs *airplane* and *tree* can vary in order to specify the arbitrary positions in which an airplane or a tree happen to be. However, features other than typical object location in vertical space can be expressed iconically by sign location. A case in point is represented by quantifiers, terms indicating quantities and amounts, such as *all* or *everyone*. As illustrated by Davidson and Gagne (2014), the exact quantity denoted by the quantifier is specified in ASL by varying sign location, as when *everyone* is signed at higher locations in signing space if referring to all of the people instead of all of my friends. Another example is provided by the corpora analyses conducted by Cates et al. (2013) in ASL and Pietrandrea (2002) in ISL, which showed that the association of a sign with a specific body part strengthens the iconicity of that sign. The ASL sign *clothes* illustrates this point as the contact with the torso contributes critically to determining sign iconicity. The use of the body to express the grammatical subject would further affect the location of signs, specifically those referring to verbs (Meir et al., 2007). As pointed out in the Introduction, sign locations anchored to body parts might conflict with sign locations corresponding to typical object positions in natural space, something occurring, for example, with *mouse*, a down concept with an ASL sign made next to the nose. Evidently, the different uses of sign location for iconicity co-exist in the language.

Sign language offers the option to vary sign location in order to specify object position, an option that, as shown by the results of Study 2, signers appear to exploit at length. The variation of sign location brought to light by our results requires that sign processing unfold in specific ways. It is not enough to assume that sign position is encoded with respect to a certain region in signing space (e.g., the head), as proposed in standard phonological theories (Brentari, 1998; Liddell & Johnson, 1989; Sandler & Lillo-Martin, 2006; Stokoe, 1960); rather, sign height must also vary to reflect the object's contextual position. Thus, sign location can be understood as a free parameter that is adjusted to encode an object's specific position. This type of two-tier encoding of sign location is reminiscent of the phonology-phonetics distinction proposed for speaking that was also evidenced at the level of brain mechanisms (Buchwald & Miozzo, 2011). Similar to certain features of speech (e.g., those related to timing) that are specified at the later phonetic level, adjustments in sign location reflecting object position are defined at a late level of sign processing. What is peculiar of the phonological-phonetic encoding taking place with signs is that it interfaces with the visuo-spatial processes responsible for object position. From a processing perspective, this implies that visuo-spatial information affects even the latest mechanisms in lexical encoding that specify signs' motor parameters (Navarrete et al., 2017).

The co-variation seen in Study 2 between sign height and object position reveals a special kind of iconicity, one enabling signs to denote specific exemplars of an object – not just a *book*, but that particular *book up there*. In this way, signs encode episodic elements and their function is not restricted to providing labels designating semantic categories such as *book* or *chair*. Words can sometimes work in a similar manner, as when the vowels of English words are lengthened to express a

remarkably large size ("it's *huuuge*!") or an exceedingly lengthy duration ("it went on for a *looong* time."). Similar to what is observed with signs, a phonological feature (vowel length) is co-opted to express episodic qualities. However, while these words denote something that is both exceptional and rather extreme, the height variability observed with sign applies more broadly. In fact, sign height was even used to distinguish between intermediate heights as those of a book laying on a table or on a shelf, or of a dog bowl placed on the floor or on a table. As our findings are limited to a single language, we do not know if the co-variation of sign height and object position is a universal feature of sign languages. What our findings show, however, is that signers exploited at length the opportunity of shaping sign location to characterize object position in the language we tested.

Several investigations (e.g., Davidson & Gagne, 2014; Taub, 2001; Wilbur, 1985) have shown that sign iconicity provides a rich source for expressing conceptual metaphors, emerging with signs like *increase*, *improve*, and *advance* by incorporating vertical-scale metaphors. As illustrated in the analyses conducted by Taub (2001), sign locations are extensively used in ASL to communicate the metaphor GOOD IS UP, in which the higher locations in the scale correspond to being better, and POWERFUL IS UP, in which the higher locations in the scale represent relative prominence and social status. By anchoring high and low locations in signing space to the ends of the metaphorical vertical scale, iconicity represents a natural device for encoding both of these metaphors. A similar use of iconicity emerged in our cross-linguistic investigation, where many of the signs referring to verbs and abstract concepts were related to these metaphors. Our cross-linguistical findings show how deeply entrenched is mapping metaphorical concepts onto vertical locations in sign language.

Conclusions

The permeability of sign space to semantic and episodic features evidenced by our findings implies a tight interface between phonology and the mechanisms encoding objects' semantic and episodic features that is unparalleled with spoken languages. Iconicity is key in this interface, as it allows the expression of salient semantic and episodic features within the constraints of phonology (Aronoff et al., 2005; Perniss et al., 2010; Taub, 2001). As our understanding of iconicity deepens, our comprehension of the interface of phonology with other mechanisms of object processing increases correspondingly. Our investigation aimed to follow this path, examining whether a salient object feature (location in vertical space) is embodied in the location of signs produced in the language.

Footnotes

1. Only between 23% to 38% of the signs were listed for the four languages we excluded. Even in these languages, signs corresponding to *up concepts* were produced above the shoulder more often than those referring to *down concepts* – 86-93% vs. 43-56%.

2. The signs elicited in Study 2 provided an additional opportunity to explore the question, examined in Study 1c, as to whether sign location varies as a function of concept typical location in natural vertical space. We correlated the ratings on concept typical location with the highest and lowest positions measured for the signs elicited by targets in contextually up and down locations. Each of these four correlations (2 sign positions x 2 sign locations) was significant ($rs > .48$; $p < .001$), demonstrating increasingly higher locations for signs corresponding to concepts naturally occurring in higher spatial regions. These findings replicated and extended those of Study 1c.

References

Aronoff, M., Meir, I., & Sandler, W. (2005). The paradox of sign language morphology. *Language, 81,* 301–344.

Baus, C., & Costa, A. (15). On the temporal dynamics of sign production: An ERP study in Catalan sign language (LSC). *Brain Research, 1609,* 40–53.

Barsalou, L. W. (2016). On staying grounded and avoiding quixotic dead ends. *Psychonomic Bulletin & Review*, *23*, 1122-1142.

Battison, R. (1974). Phonological deletion in American Sign Language. *Sign Language Studies, 5*, 1-19.

Bellugi, U., Klima, E. S., & Siple, P. (1975). Remembering in signs. *Cognition, 3,* 93-125.

Bergen, B. K., Lindsay, S., Matlock, T., & Narayanan, S. (2007). Spatial and linguistic aspects of visual imagery in sentence comprehension. *Cognitive Science, 31*, 733–764.

Bickford, J. A. (2005). *The signed languages of Eastern Europe*. Dallas, TX: SIL International.

Brentari, D. (1998). *A prosodic model of sign language phonology*. Cambridge, MA: MIT Press.

Brentari, D., Coppola, M., Mazzoni, L., & Goldin-Meadow, S. (2012). When does a system become phonological? Handshape production in gesturers, signers, and homesigners. *Natural Language & Linguistic Theory*, *30*, 1-31.

Buchwald, A., & Miozzo, M. (2011). Finding levels of abstraction in speech production: Evidence from sound-production impairment. *Psychological Science*, *22*, 1113-1119.

Cates, D., Gutiérrez, E., Hafer, S., Barrett, R., & Corina, D. (2013). Location, location, location. *Sign Language Studies*, *13*, 433-461.

Chasteen, A. L., Burdzy, D. C., & Pratt, J. (2010). Thinking of God moves attention. *Neuropsychologia*, 48, 627-630.

Davidson, K., & Gagne, D. (2014). Context made visible: On the structure of quantified noun phrases. Talk presented at the North East Linguistic Society conference, Boston, MA.

de l'Épée, C-M. (1776). *Institution des sourds et muets par la voie des signes méthodiques, ouvrage qui contient le project d'une langue universelle, par l'entremise des signes naturels assujettis à une methode*. Paris: Nyon.

de la Vega, I., Dudschig, C., De Filippis, M., Lachmair, M., & Kaup, B. (2013). Keep your hands crossed: The valence-by-left/right interaction is related to hand, not side, in an incongruent hand–response key assignment. *Acta Psychologica*, *142*, 273-277.

Demey, E., & van der Kooij, E., (2008). Phonological patterns in a dependency model: Allophonic relations grounded in phonetic and iconic motivation. *Lingua, 118*, 1109-1138.

Dingemanse, M., Blasi, D. E., Lupyan, G., Christiansen, M. H., & Monaghan, P. (2015). Arbitrariness, iconicity, and systematicity in language. *Trends in Cognitive Sciences, 19,* 603–615.

Dudschig, C., de la Vega, I., De Filippis, M., & Kaup, B. (2014). Language and vertical space: On the automaticity of language action interconnections. *Cortex*, *58*, 151-160.

Dudschig, C., Souman, J., Lachmair, M., de la Vega, I., & Kaup, B. (2013). Reading "sun" and looking up: The influence of language on saccadic eye movements in the vertical dimension. *PloS One*, *8*, e56872.

Emmorey, K. (2002). *Language, cognition, and the brain: Insights from sign language research.* Mahway, NJ: Lawrence Erlbaum Associates Inc.

Emmorey, K. (2014). Iconicity as structure mapping. *Philosophical Trans- actions of the*

Royal Society of London, Series B: Biological Sciences, 369, 20130301.
Emmorey, K, & McCullough, S., & Brentari, D. (2003). Categorical perception in American Sign Language. *Language and Cognitive Processes, 18*, 21-45.
Estes, Z., Verges, M., & Adelman, J. S. (2015). Words, objects, and locations: Perceptual matching explains spatial interference and facilitation. *Journal of Memory and Language*, *84*, 167-189.
Fontana, S., Corazza, S., Braem, P. B., & Volterra, V. (2015). Language research and language community change: Italian Sign Language 1981–2013. *International Journal of the Sociology of Language*, *236*, 1-30.
Frishberg, N. (1975). Arbitrariness and iconicity: historical change in American Sign Language. *Language*, 51, 696-719.
Gozli, D. G., Chasteen, A. L., & Pratt, J. (2013). The cost and benefit of implicit spatial cues for visual attention. *Journal of Experimental Psychology: General*, *142*, 1028-1046.
Johnson, R. E., & Liddell, S. K. (2011). 1984. A Segmental Framework for Representing Signs Phonetically. *Sign Language Studies* 11: 408–63.
Kegl, J., Senghas, A., & Coppola, M. (1999). Creation through contact: sign language emergence and sign language change in Nicaragua. In M. DeGraff (Ed.), *Language creation and language change: Creolization, diachrony, and development* (pp. 197-237). Cambridge, MA: MIT Press.
Klima, E. S., & Bellugi, U. (1979). *The signs of language*. Cambridge, MA: Harvard University Press.
Ladefoged, P., & Maddieson, I. (1996). *The Sounds of the World's Languages.* Oxford: Blackwell.
Lakoff, G., & Johnson, M. (1980). *Metaphors we live by.* Chicago: Chicago University Press b.
Lebois, L. A., Wilson-Mendenhall, C. D., & Barsalou, L. W. (2015). Are Automatic Conceptual Cores the Gold Standard of Semantic Processing? The Context-Dependence of Spatial Meaning in Grounded Congruency Effects. *Cognitive Science, 39*, 1764-1801.
Liddell, S. K., & Johnson, R. E. (1989). American Sign Language: the phonological base. *Sign Language Studies, 64*, 197-277.
Lucas, C., Bayley, R., Rose, M., & Wulf, A. (2002). Location variation in American Sign Language. *Sign Language Studies, 2*, 407–440.
Mahon, B. Z., & Hickok, G. (2016). Arguments about the nature of concepts: Symbols, embodiment, and beyond. *Psychonomic Bulletin & Review*, *23*(4), 941-958.
Meir, I. (2010). Iconicity and metaphor: Constraints on metaphorical extension of iconic forms. *Language*, *86*, 865-896.
Meir, I., Padden, C. A., Aronoff, M., & Sandler, W. (2007). Body as subject. *Journal of Linguistics*, *43*, 531-563.
Meir, I., & Sandler, W. (2008). *A language in space: The story of Israeli Sign Language*. New York: Taylor Francis.
Meteyard, L., & Vigliocco, G. (2009). Verbs in space: Axis and direction of motion norms for 299 English verbs. *Behavior Research Methods, 41*, 565–574.
Navarrete, E., Peressotti, F., Lerose, L., & Miozzo, M. (2017). Cascading activation in sign production. *Journal* of *Experimental Psychology. Learning, Memory, and Cognition, 43*, 302-318.
Padden, C. (2010). Sign language geography. *Deaf around the world: The impact of language*, 19-38.

Papesh, M. H. (2015). Just out of reach: On the reliability of the action-sentence compatibility effect. *Journal of Experimental Psychology: General*, *144*, e116–e141.

Perniss, P., Thompson, R., & Vigliocco, G. (2010). Iconicity as a general property of language: evidence from spoken and signed languages. *Frontiers in Psychology*, *1*, 227.

Petrova, A., Navarrete, E., Suitner, C., Sulpizio, S., Reynolds, M., Job, R., Peressotti, F. (2018). Spatial congruency effects, just not for words: Looking into Estes, Verges, Barsalou (2018). *Psychological Science, 29*, 1195-1199.

Pretato, E., Peressotti, F., Bertone, C., & Navarrete, E. (2018). The iconicity advantage in sign production: The case of bimodal bilinguals. *Second Language Research*, *34*, 449-462.

Pietrandrea, P. (2002). Iconicity and arbitrariness in Italian sign language. *Sign Language Studies*, *2*, 296-321.

Rommers, J., Meyer, A. S., & Huettig, F. (2013). Object shape and orientation do not routinely influence performance during language processing. *Psychological Science, 24*, 2218-2225.

Sandler, W. (1989). *Phonological representation of the sign: Linearity and nonlinearity in American Sign Language*. Dordrecht: Foris.

Sandler, W., & Lillo-Martin, D. (2006). *Sign language and linguistic universals*. Cambridge, United Kingdom: Cambridge University Press.

Sandler, W., Meir, I., Padden, C., & Aronoff, M. (2005). The Emergence of Grammar in a New Sign Language. *Proceedings of the National Academy of Sciences*, *102*, 2661–2665.

Stanfield, R. A., & Zwaan, R. A., (2001). The effects of implied orientation derived from verbal context in picture recognition. *Psychological Science, 12*, 153-156.

Stokoe, W. C. (1960). Sign language structure. *In Studies in Linguistics: Occasional Papers*, *Vol. 8*. Buffalo, NY: University of Buffalo Press.

Taub, S. F. (2001). *Language from the body: Iconicity and metaphor in American Sign Language*. New York, NY: Cambridge University Press.

Thornton, T., Loetscher, T., Yates, M. J., & Nicholls, M. E. R. (2013). The highs and lows of the interaction between word meaning and space. *Journal of Experimental Psychology: Human Perception and Performance, 39*, 964–973.

Tyrone, M. E., & Mauk, C. E. (2010). Sign lowering and phonetic reduction in American Sign Language. *Journal of Phonetics*, *38*, 317-328.

Verges, M., & Duffy, S. (2009). Spatial Representations Elicit Dual‐Coding Effects in Mental Imagery. *Cognitive Science*, *33*, 1157-1172.

Vinson, D., Thompson, R. L., Skinner, R., & Vigliocco, G. (2015). A faster path between meaning and form? Iconicity facilitates sign recognition and production in British sign language. *Journal of Memory & Cognition, 82,* 56–85.

Wilbur, R. B. (1987). *American Sign Language: Linguistic and applied dimensions.* Boston: Little, Brown.

Appendix A. Signs of concepts examined in Study 1a (the number languages analyzed for each sign is reported in parentheses)

1. *Up concepts*

(a) *Concrete Objects*: airplane (19), arch (14), balloon (17), bell (16), bird (19), cap (15), castle (17), ceiling (16), champion (16), cloud (18), collar (19), crown (18), curtains (19), elevator (19), fireworks (17), flag (16), giraffe (18), hat (18), helicopter (16), helmet (19), hill (16), kite (9), leaf (14), lightning (15), moon (17), mountain (17), parachute (15), peak (15), rainbow (12), rocket (17), roof (16), satellite (17), sky (19), smoke (15), star (17), sun (20), tree (19), umbrella (15), volcano (16), window (18);

(b) *Abstract concepts*: ability (17), adventure (14), angel (16), birthday (14), comfort (14), confidence (19), freedom (16), glory (14), god (20), happy (15), heaven (16), height (20), holiday (16), humor (16), joy (17), kindness (15), loyalty (16), miracle (15), passion (15), prestige (10), pride (13), success (16), talent (13), victory (15), wedding (17);

(c) *Verbs*: to ascend (18), to build (12), to climb (18), to delight (16), to desire (19), to elevate (14), to emerge (16), to escalate (13), to expand (16), to fill (14), to fly (14), to grow (16), to hope (18), to improve (13), to inflate (17), to jump (16), to kiss (18), to lift (12), to respect (16), to rise (15), to smile (19), to sprout (10), to stack (15), to support (13), to throw (16).

2. *Down concepts*

(a) *Concrete Objects*: basement (14), corner (17), crab (16), depression/valley (7), ditch (9), drop (16), floor (13), grass (11), ground (10), lake (9), mouse (19), pants (16), road (15), root (13), sand (14), seed (13), shell (12), shoe (15), skateboard (11), skates (15), sled (9), snake (18), sock (14), stone (17), turtle (15), valley (15), whale (13), wheel (11), worm (17);

(b) *Abstract concepts*: anger (16), bankrupt (16), crisis (17), danger (17), death (19), depressed (17), depression (13), devil/demon (18), disaster (8), error/mistake (17), evil (18), failure (13), fear (17), funeral (11), guilt (16), hunger (18), ignorance (18), pain (14), problem (12), sorrow (15), stress (16), suicide (8), tragedy (15), trouble (17);

(c) *Verbs*: to collapse (15), to decline (6), to decrease (17), to demolish (14), to depress (14), to deteriorate (16), to dig (11), to dive (14), to fall (14), to greed (17), to pour (15), to punish (19), to slide (18), to steal (16), to upset (18).

Appendix B. ASL and ISL signs corresponding to concepts that typically occur in high, 'middle,' and low locations in natural space.

1. *ASL*

(a) *Up concepts*: acceptance (5.2), airplane (5.1), arch (4.0), to arise (4.5), balloon (4.0), bell (4.1), bird (4.8), birthday (4.3), to build (4.2), cableway (4.8), cap (3.5), castle (4.3), ceiling (4.3), champion (5.1), to climb (4.9), cloud (5.8), collar (3.1), comfort (4.1), crown (4.7), curtains (3.5), to delight (4.8), to desire (4.4), eagle (5.1), to elevate (5.0), excellence (5.4), excitement (4.9), to expand (4.7), to fill (3.3), fireworks (5.5), flag (4.2), to float (4.3), freedom (5.4), giraffe (4.2), god (6.5), to grow (4.4), hanger (3.5), hat (3.7), health (4.9), heaven (6.6.), height (5.1), helicopter (5.6), helmet (3.4), hill (4.1), holiday (4.5), honesty (5.0), hood (3.4), to hop (3.0), to hope (5.2), to hug (4.4), humor (4.8), improvement (5.0), to increase (4.4), joy (4.7), kindness (5.2), to kiss (4.4), kite (4.9), leaf (3.2), to lift (4.2), lightning (5.3), loyalty (5.2), miracle (5.5), moon (6.7), mountain (5.7), nest (3.9), optimism (5.3), parachute (5.2), passion (5.3), peak (5.7), perfection (5.3), planet (5.9), pleased (4.9), pride (4.8), rainbow (5.7), respect (4.8), rocket (5.8), roof (4.3), satellite (6.3), sky (6.3), to smile (4.4), smoke (3.9), to splash (3.1), to sprout (2.7), to stack (3.5), to stand (3.7), star (6.7), success (5.6), sun (6.8), support (4.3), talent (5.0), top (5.6), tree (4.2), umbrella (3.7), volcano (5.3), wealth (5.0), wedding (4.5), window (4.0);

(b) '*Middle' concepts*: bag (3.0), banana (3.3), bear (3.5), belt (2.7), bicycle (2.8), book (3.6), bottle (2.4), bowl (2.8), bread (3.5), bridge (4.2), broom (2.7), bus (2.6), cake (3.3), car (2.3), cat (2.6), catch (3.5), chain (2.7), chair (2.9), church (3.5), coin (2.5), corn (2.4), dart (3.2), dirty (1.6), dress (3.2), elephant (3.7), faucet (2.9), fence (2.7), flower (2.8), forest (3.9), fork (3.0), grill (3.0), gun (2.6), hatred (2.9), horse (3.3), house (3.6), jail (2.3), key (3.0), lamp (2.8), lemon (2.8), mask (3.2), mirror (3.7), mushroom (2.1), necklace (3.9), pencil (2.9), pig (2.7), potato (2.1), sauce (2.5), scarf (3.7), scissors (2.5), sea (2.3), shadow (1.8), sheep (2.8), shirt (3.2), shower (3.8), to sit (2.4), sofa (2.6), table (2.9), telephone (3.1), telescope (4.0), television (2.9), towel (2.8), train (3.3), tripod (3.1), truck (2.7), tunnel (2.2);

(c) *Down concepts*: anger (3.0), basement (1.6), basin (2.3), bed (2.5), bomb (3.3.), bug (2.4), chicken (2.7), claw (2.4), to collapse (1.9), corner (3.2), crab (2.3), crisis (2.5), crocodile (2.1), to crumble (1.8), to crush (2.5), danger (3.8), death (2.4), to decrease (2.1), to deflate (2.0), to demolish (1.7), depressed (2.3), to descend (1.9), devil (2.1), to dig (1.5), dirt (1.7), disappointment (3.0), ditch (1.7), to dive (2.0), to drain (1.8), to drip (2.4), to drop (2.0), to dunk (3.3), earth (3.8), evil (2.7), failure (1.8), to fall (2.1), fear (3.3), fish (1.7), floor (2.0), foundation (1.7), frog (2.3), to frown (2.6), funeral (2.0), grass (2.2), greed (3.3), guilt (3.2), hell (1.5), hole (1.3), hoof (2.3), hunger (2.4), illness (2.8), injury (2.6), lake (2.7), land (2.9), to lay (2.5), loneliness (2.5), mistake (1.9), mouse (2.2), pants (2.7), penalty (2.0), to plummet (1.6), to pour (2.6), poverty (2.2), rail (2.4), road (2.2), root (1.5), rug (2.3), sad (2.6), sand (1.9), sandals (2.2), seed (1.9), shellfish (2.6), shoe (2.2), skateboard (2.6), skates (2.3), sled (2.5), slip (2.8), snail (2.2), snake (1.8), sock (2.4), to spill (2.0), to starve (2.2), to steal (3.5), stone (2.0), stress (3.4), subway (1.8), sunset (4.4), trouble (3.1), to tumble (2.4), turtle (2.4), underground (1.4), upset (3.0), valley (2.2), whale (3.0), wheel (2.7), worm (1.8).

2. *ISL*

(a) *Up concepts*: ability (4.5), adventure (4.8), airplane (6.4), angel (5.6), antenna (5.6), arch (5.4), to arise (4.3), to ascend (5.0), balloon (5.6), bell (5.6), birthday (4.4), blimp (5.6), to boost (4.8), branch (5.6), to build (4.7), cableway (5.7), cap (4.7), castle (5.3), champion (4.3), chandelier (5.6), happy (4.8), chimney (5.6), to climb (5.2), cloud (6.3), collar (4.0), comfort (4.0), content (5.2), crown (4.9), curtains (4.4), to delight (5.1), desire (5.4), to elevate (5.3), to emerge (3.9), enjoyment (4.8), to escalate (4.2), excellence (4.7), excitement (5.3), to expand (4.0), to fill (3.4), fireworks (6.4), flag (5.4), to float (2.9), to fly (6.1), freedom (5.6), giraffe (4.9), glory (5.1), god (5.8), to grow (4.5), happy (4.8), hat (5.0), health (4.8), heaven (5.8), height (5.4), helicopter (6.1), helmet (4.2), hill (5.0), holiday (4.3), honesty (5.4), hood (4.5), to hop (4.2), to hope (4.7), to hug (5.0), humor (5.1), to inflate (4.2), joy (5.3), kindness (5.0), to kiss (4.4), kite (6.0), to launch (5.0), leaf (4.0), to lift (4.7), lightning (5.9), loyalty (5.4), miracle (5.1), monument (4.4), moon (6.4), mountain (6.1), parachute (5.7), passion (5.2), peak (5.9), perfection (4.6), planet (5.7), pleased (4.3), pride (4.4), rainbow (6.2), respect (5.0), rocket (4.9), roof (5.6), satellite (6.7), sauce (3.5), sky (6.8), to smile (5.2), smoke (4.4), snout (3.4), to splash (3.9), to sprout (2.8), to stack (3.3), to stand (4.2), star (6.4), success (4.7), sun (6.8), to support (4.6), tip (4.4), top (6.3), tree (4.7), to throw (4.7), ufo (6.6), umbrella (4.6), victory (5.2), volcano (5.6), warmth (5.1), wedding (4.3), wig (4.3), window (4.3), wisdom (5.4);

(b) '*Middle' concepts*: to adopt (4.5), advice (4.4), to alarm (3.6), anxiety (4.1), to arrive (3.7), bag (3.2), banana (3.1), banner (4.3), barn (3.4), bear (4.0), belief (4.4), belt (2.9), bicycle (3.0), bog (1.5), book (4.1), bowl (2.9), bowtie (3.7), bread (3.2), bridge

(4.1), broom (2.3), to burn (4.0), bus (3.7), cake (3.6), car (3.1), cat (2.5), chain (2.9), chair (2.8), to chase (3.7), church (4.4), to collect (3.1), to cost (3.9), cowboy (3.4), to crawl (1.9), to cross (2.9), dart (4.0), to dream (5.4), dress (3.4), duty (3.9), effort (4.4), elephant (4.3), to exist (5.0), faucet (3.1), fence (2.5), to escape (3.2), flower (2.3), football (2.8), forest (3.5), fur (3.2), glass (3.2), glasses (4.5), grief (2.9), grill (2.6), gun (3.5), halo (5.4), harbor (3.0), hatred (2.7), horse (4.0), house (3.7), hotel (3.4), hour (3.5), to impact (3.0), interest (4.9), jail (3.0), justice (4.6), key (3.2), to kick (2.4), ladder (4.1), lamp (3.7), lecture (4.3), lemon (3.4), lowness (2.1), mask (4.3), menace (3.5), method (4.7), mirror (3.8), moat (1.5), month (3.8), moral (5.0), mushroom (1.7), necklace (3.8), pan (2.8), parrot (4.7), pencil (3.0), pig (2.1), pleasure (5.5), pole (4.4), porch (4.2), poster (4.6), potato (1.8), power (5.0), prayer (3.9), to prevail (3.8), to pull (3.9), to push (3.8), to quit (3.0), race (3.2), to rest (3.5), to retrieve (2.8), to reward (4.7), safety (4.9), satire (4.4), scarf (3.8), scissors (2.8), sea (3.0), to serve (3.2), shadow (2.6), sheep (2.2), to shine (5.1), shirt (3.4), shower (3.8), to sit (2.7), to slump (2.5), to sneeze (3.3), sofa (2.9), spirit (5.6), to stay (3.5), to stop (3.5), sugar (3.0), to swap (3.4), table (3.5), telephone (3.9), telescope (5.0), television (3.6), tennis (3.2), to thanks (4.8), theory (4.8), ticket (3.0), time (5.3), to toast (4.1), towel (2.8), toy (3.1), train (3.1), trefoil (2.3), tripod (2.6), truck (3.4), truth (5.2), tunnel (1.8), vase (3.4), vigor (4.9), volleyball (4.6), to wait (3.7), to walk (3.6), to wash (3.4), to write (3.6);

(c) *Down concepts*: accident (2.8), anger (4.3), base (2.2), burrow (1.6), cancer (2.7), claw (2.2), to collapse (2.5), cord (2.4), corn (2.8), corner (2.7), crab (1.8), crisis (3.2), crocodile (2.4), to crumble (2.5), to crush (3.0), danger (3.7), death (3.2), to decline (3.0), to decrease (2.7), to deflate (3.4), depression (2.3), to descend (2.7), to destruct (2.7), to deteriorate (3.3), devil (3.2), to dig (1.6), disaster (4.0), to drip (2.9), drop (3.5), earth (3.8), evil (2.8), failure (3.4), to fall (2.4), fear (3.3), fish (1.8), floor (1.6), fork (2.8), frog (2.0), to frown (3.5), funeral (2.3), gloomy (2.6), grass (1.8), grave (2.1), greed (2.6), guilt (2.9), to hang (4.5), hell (2.3), hole (1.2), hoof (1.3), ignorance (2.4), illness (3.2), injury (3.2), land (1.1), lake (2.8), to lay (1.8), loser (3.1), to lower (2.7), melancholy (3.0), mistake (3.4), mole (1.0), mouse (1.8), pain (3.2), pants (2.6), pavement (1.6), paw (2.1), penalty (3.1), to plummet (2.9), to pour (3.0), to punish (2.8), rail (1.4), rain (4.6), road (2.3), root (1.1), rug (1.5), sand (1.5), seashell (1.7), seed (1.5), shoe (1.5), skateboard (2.6), skates (1.5), sled (3.0), snail (1.4), snake (2.0), sorrow (3.1), to spill (3.1), stone (1.6), street (2.5), subway (1.3), suicide (3.6), sunset (5.0), trouble (4.4), to tumble (2.4), turtle (1.8), valley (3.7), whale (1.8), wheel (2.5), to wither (2.5), worm (1.3).

Appendix C. Objects visually presented in Study 2 in contextually low vs. high positions; ratings for location in the natural vertical space are shown in brackets: (1) *airplane* (6.4), on the ground/in the sky; (2) *basketball* (5.1), on the floor/in the basket; (3) *bat* (4.8), just above ground level/in the sky; (4) *bee* (4.7), just above ground level/above the roof; (5) *bell* (5.6), on the ground/in the steeple; (6) *bike* (3.0), on the road/on the roof of the car; (7) *book* (4.1), on the table/on the top shelf; (8) *bottle* (2.9), on the floor/on the shelf; (9) *box* (4.4), on the floor/on the shelf; (10) *bridge* (4.1), over the river/over the canyon; (11) *butterfly* (4.5), on the garden flowers/above the tree top; (12) *cage* (3.8), on the table/hanging from the ceiling; (13) *car* (3.1), on the street/on a high bridge; (14) *dog bowl* (2.9), on the floor/on the table; (15) *dolphin* (1.8), underwater/above water; (16) *egg* (3.2), on the table/in the nest; (17) *fish* (1.8), in the water/above water; (18) *flag* (5.4), in the park/on a mountain top; (19) *flower pot* (3.4), on the floor/on the window ledge; (20) *frog* (2.0), underwater/on the shore; (21) *ghost* (4.9), in a room/in the sky; (22) *helicopter* (6.1), on the ground/in the sky; (23) *leaf* (4.0), on the ground/in the tree; (24) *motorbike* (3.2), on the road/jumping over the cliff; (25) *pear* (3.4), on the ground/hanging in the tree; (26) *rocket* (4.9), on the launch pad/in outer space; (27) *ship* (3.0), at the bottom of the see/on the water; (28) *shovel* (2.3), at the bottom of the pit/on top of the dirt hill; (29) *sock* (1.5), in the basket/hanging from the cloth line; (30) *socket* (2.4), at ground level/above the kitchen counter; (31) *submarine* (1.2), under water/docked in the harbor; (32) *suitcase* (4.4), on the floor/on the top bunk; (33) *tiger* (2.8), on the ground/in the tree; (34) *traffic light* (4.4), on the ground/hanging from the power line; (35) *train* (3.1), in the meadow/on a high bridge; (36) *tree* (4.7), in the park/on the top of the hill; (37) *turtle* (1.8), at the bottom of the see/on the shore.

Table 1. Number of signs analyzed across languages

Sign Language[a]	Excluded[b] Signs	Signs for Up[c] Concepts	Signs for Down[d] Concepts	Analyzed Signs
American	12	81	57	138
Austrian	13	71	63	134
Brazilian	8	59	30	89
British	13	78	50	128
Czech	8	77	57	134
Estonian	8	80	52	132
French	8	78	47	125
German	10	76	60	136
Icelandic	8	78	58	136
Italian	10	81	48	129
Latvian	9	82	53	135
Lithuanian	14	75	50	125
Polish	16	68	45	113
Portuguese	6	77	45	122
Rumanian	5	48	32	80
Russian	14	71	49	120
Spanish	10	75	53	128
Swedish	7	66	49	115
Turkish	7	64	49	113
Ukrainian	7	53	37	90
Total	*193*	*1438*	*984*	*2422*

[a] We adopted the English names listed in Ethnologue (https://www.ethnologue.com). Different names might be used for these languages (e.g., Deutsche Gebärdensprache [DGS] for the German Sign language).
[b] Signs were excluded from analyses if it could not be reliably determined if they were produced above the signer's shoulders.
[c] Signs referring to concepts with an upward spatial association (e.g., *cloud, passion, to jump*).
[d] Signs referring to concepts with a downward spatial association (e.g., *root, problem, to decrease*).

Table 2. Correlations between spatial ratings and sign spatial parameters

Sign Referents	N	Sign Vertical Space Parameters		
		Highest Point	Lowest Point	Vertical Extension
ASL				
Concrete Objects	154	*r = .58, p < .0001*	*r = .24, p = .002*	*r = .31, p < .0001*
Abstract Concepts	55	*r = .35, p = .007*	r = .16, p > .05	r = .12, p > .05
Verbs	48	*r = .34, p = .01*	*r = .35, p = .01*	r = .16, p > .05
ISL				
Concrete Objects	183	*r = .62, p < .0001*	*r = .43, p < .0001*	*r = .30, p < .0001*
Abstract Concepts	90	*r = .20, p = .05*	r = .12, p > .05	r = .10, p > .05
Verbs	84	*r = .29, p = .007*	r = .13, p > .05	r = .12, p > .05

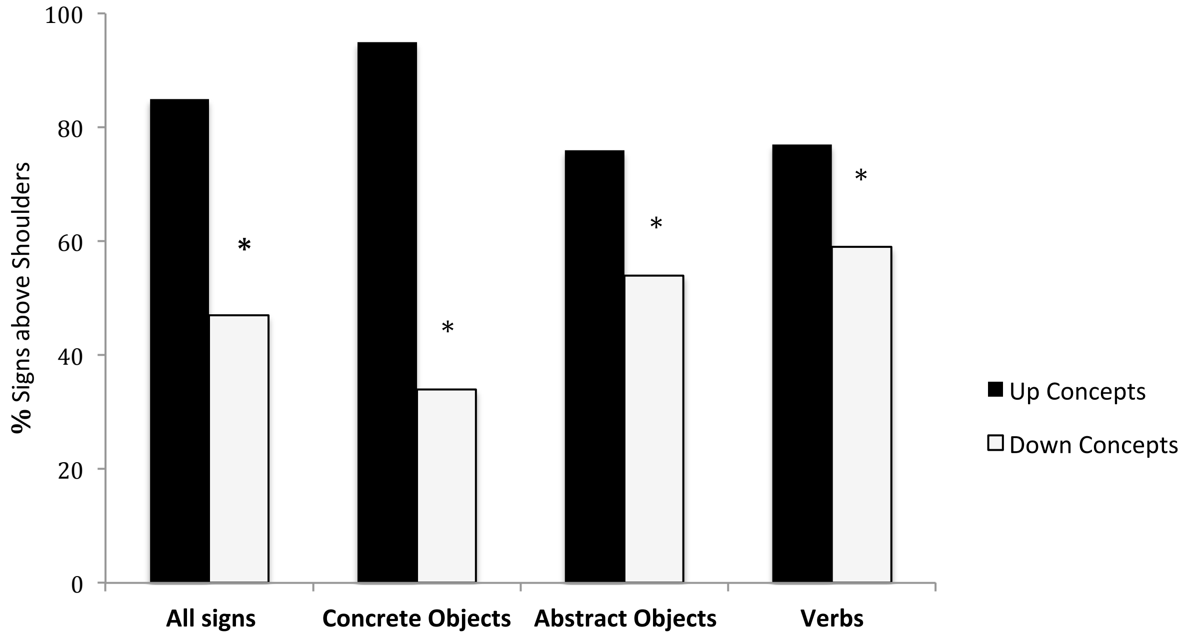

Figure 1. Percentage of signs corresponding to concepts with an upward spatial association (*up concepts*) or a downward spatial association (*down concepts*) produced above the signer's shoulders. The signs were from the twenty languages listed in Table 1. Signs represented concrete objects (e.g., *roof*, *worm*), abstract concepts (e.g., *passion*, *guilt*) or verbs (e.g., *to jump*, *to decrease*). In all conditions, signs referring to up concepts were more likely to occur above the signer's shoulders. * Differences between signs corresponding to up vs. down concepts with p < .0001.

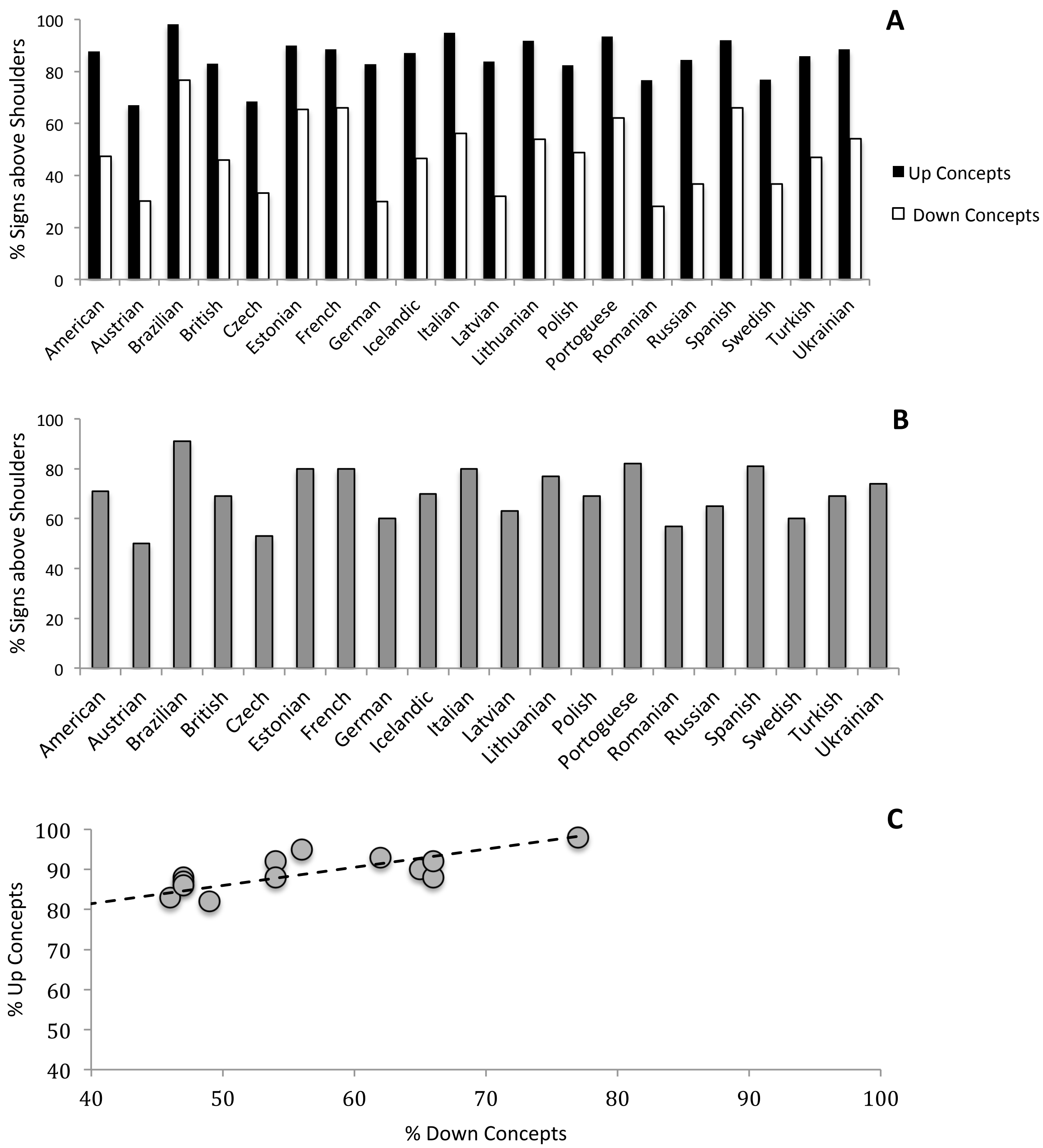

Figure 2. *Panel A*: In each language, signs corresponding to concepts with an upward spatial association (*up concepts*; e.g., *cloud*) were more likely to occur above the signer's shoulders than concepts with a downward spatial association (*down concepts*; e.g., *root*) (ps(Bonferroni corrected) < .05). *Panel B*: Total signs produced in each language above the signer's shoulders. *Panel C*: Percentage of signs representing up and down concepts produced above the signer's shoulders; the broken line shows the linear correlation (r = .81, p < .0001).

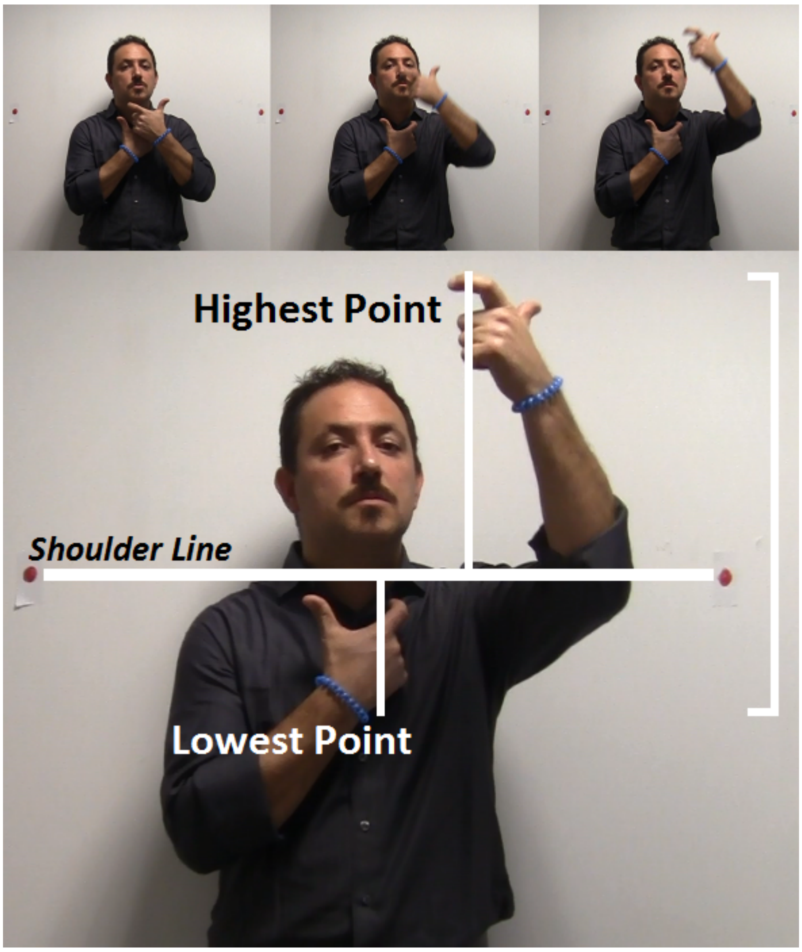

Figure 3. *Top*: Time-lapse of the ISL sign *giraffe*. *Bottom*: the frame showing the highest and lowest points of the sign used for analyses. The red dots to the sides of the signer were used to draw the shoulder line that functioned as baseline. The vertical line on the right, which extended from the lowest to the highest points, indicated the sign vertical extension.

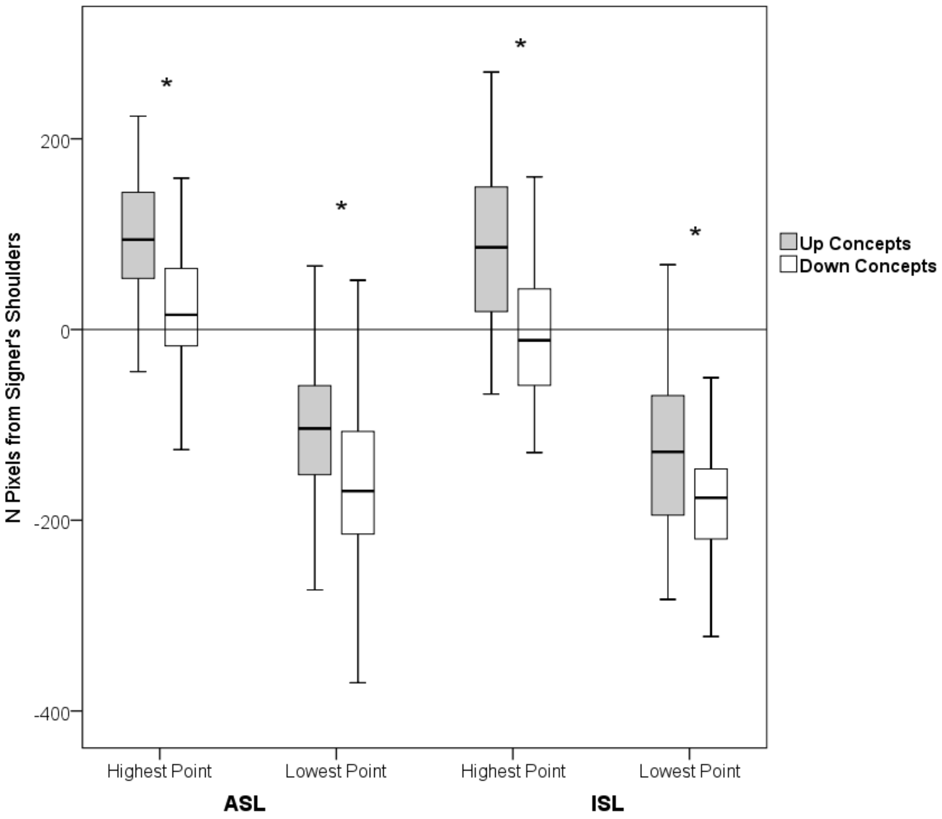

Figure 4. Boxplots showing the distribution of highest and lowest points for signs corresponding to concepts with an upward spatial association (*up concepts*; e.g., *cloud*) or a downward spatial association (*down concepts*; e.g., *root*). Signs were produced in ASL (left panel) and ISL (right panel). Distance (in pixels) from the signer's shoulders (at 0). Positive and negative values correspond to points above and below the signer' shoulders, respectively. * Differences between signs corresponding to up vs. down concepts with p < .0001.

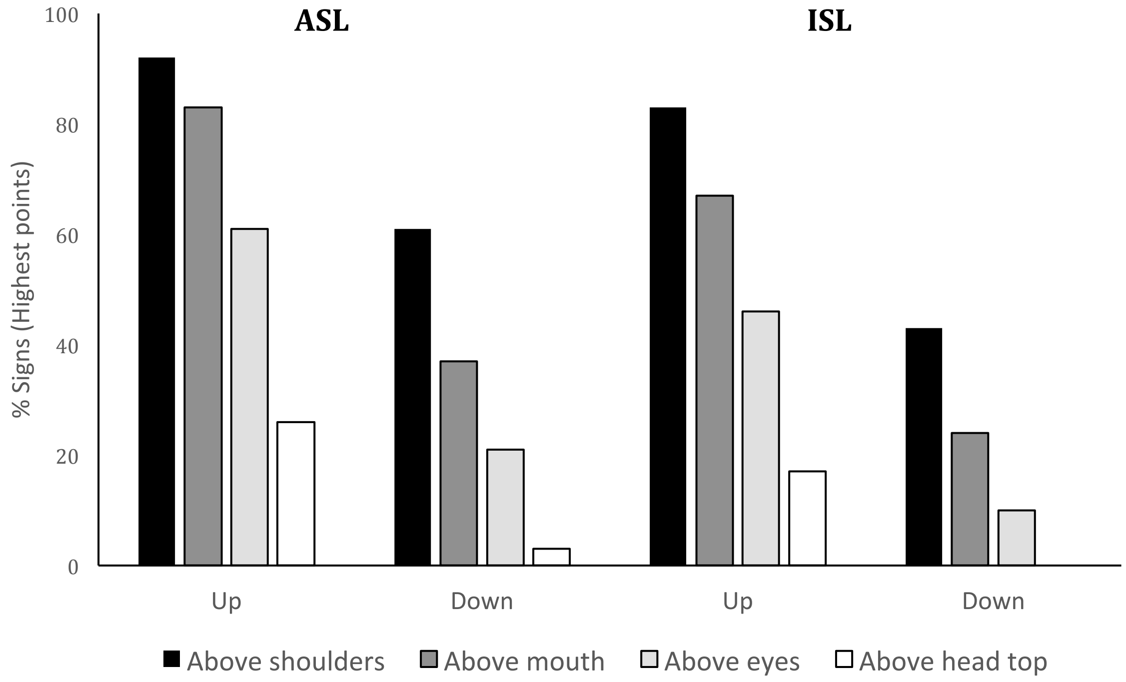

Figure 5. Percentage of signs referring to up and down concepts that were produced with the highest point above specific body landmarks (shoulder, mouth, eyes, head top) in ASL (left panel) and ISL (right panel).

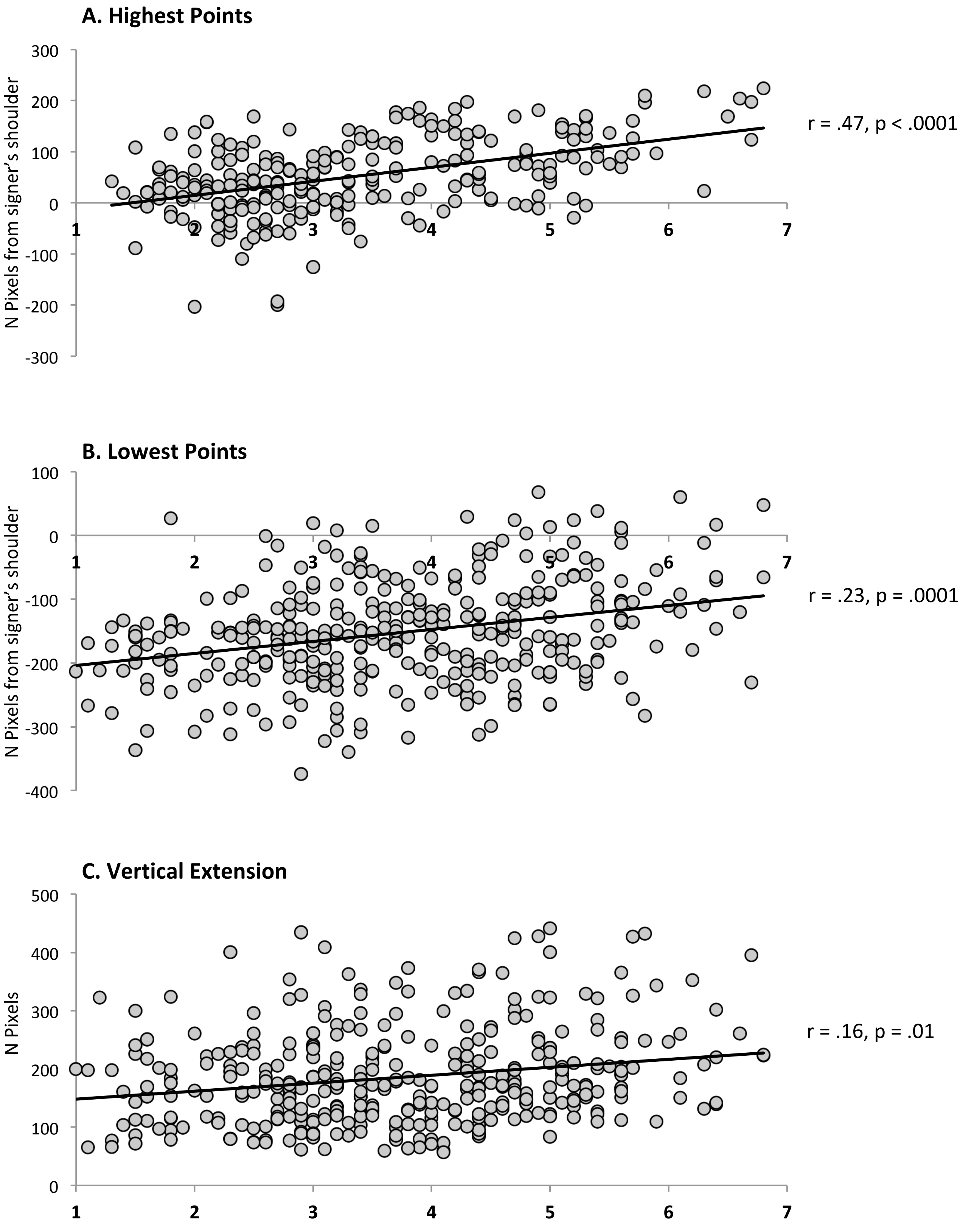

Figure 6. Correlations between spatial ratings and sign vertical space parameters (*Panel A*: highest points; *Panel B*: lowest points; *Panel C*: vertical extension). For highest and lowest points we report the distance (in pixels) from the signer's shoulders (at 0). Positive and negative values corresponded to locations above and below the signer's shoulders, respectively. Spatial ratings were expressed on a 1-7 point scale (1 = lowest position in natural space; 7 = highest position in natural space). The line shows the linear correlation. Data based on ASL signs.

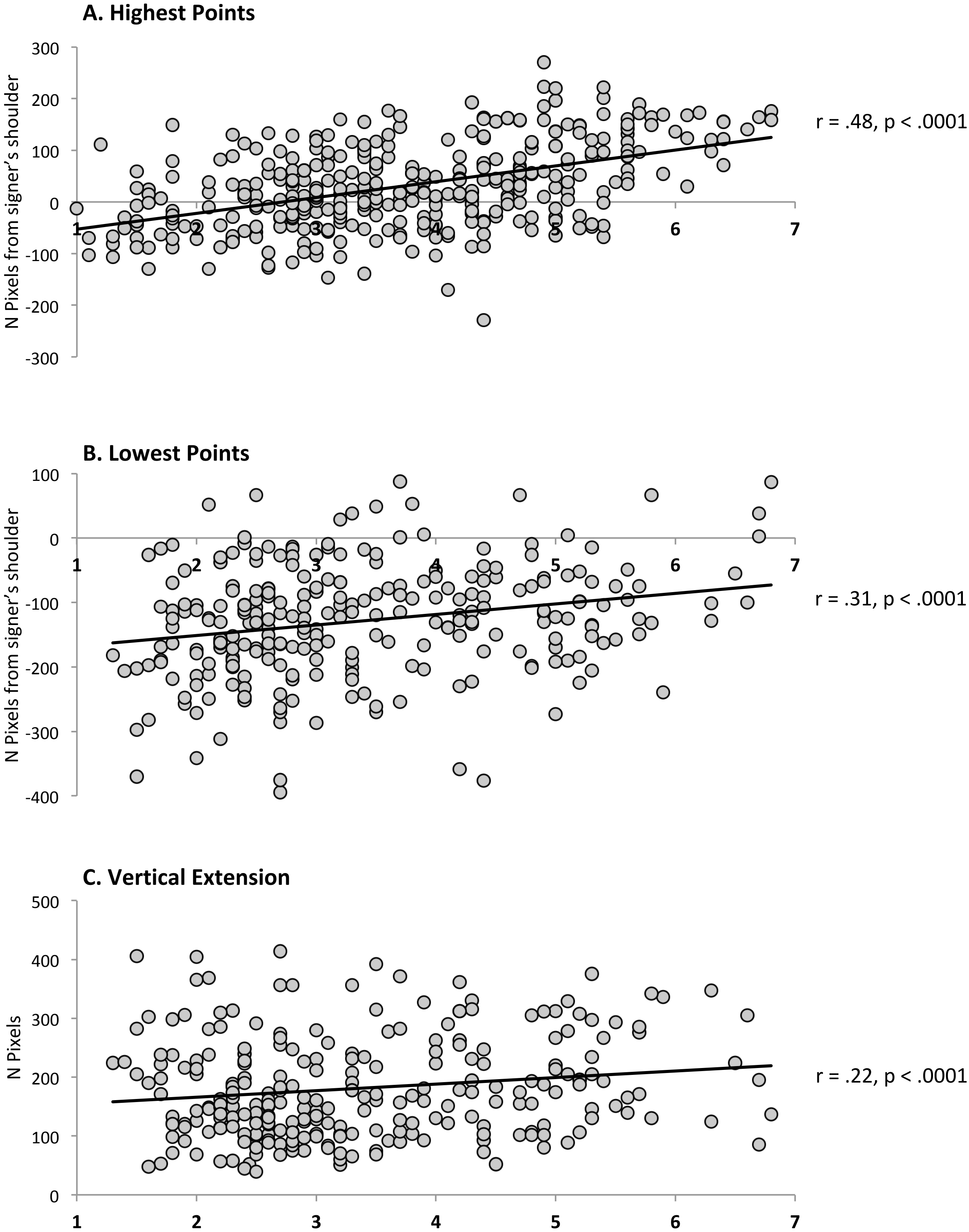

Figure 7. Correlations between spatial ratings and sign vertical space parameters (*Panel A*: highest points; *Panel B*: lowest points; *Panel C*: vertical extension). For highest and lowest points we report the distance (in pixels) from the signer's shoulders (at 0). Positive and negative values corresponded to locations above and below the signer's shoulders, respectively. Spatial ratings were expressed on a 1-7 point scale (1 = lowest position in natural space; 7 = highest position in natural space). The line shows the linear correlation. Data based on ISL signs.

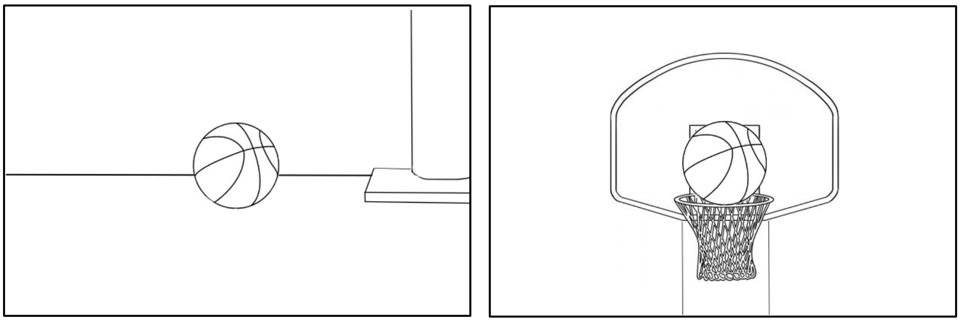

Figure 8. Example of the context used in Study 2 to vary the position height of the target object (in this case *basketball*). Low context (left); High context (right). Note that in both cases the target object appeared in the same position on the computer screen.

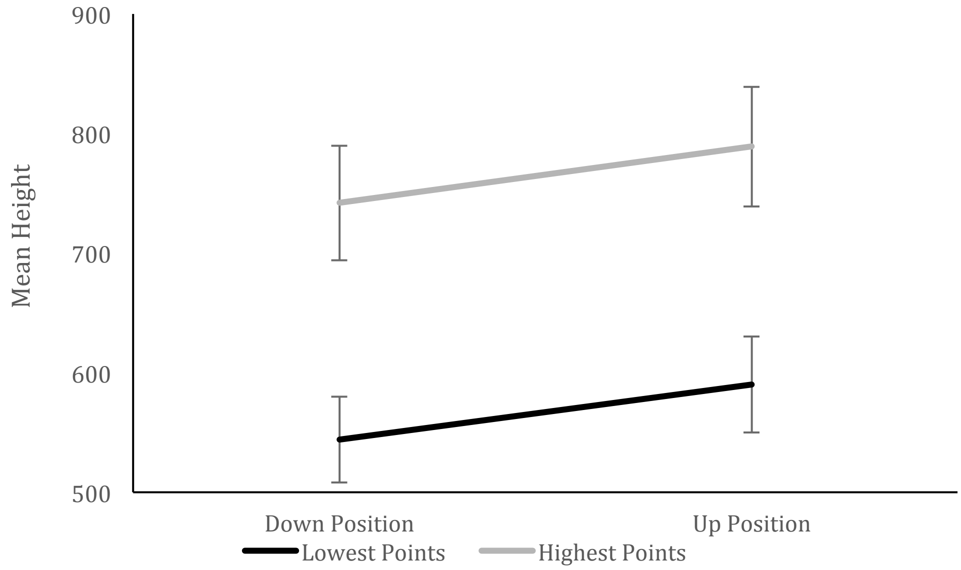

Figure 9. Mean highest and lowest locations (measured in pixels) of signs corresponding to target objects shown at down and high contextual positions (Study 2). Error bars display standard errors. With both points, signs were articulated at higher locations for target objects appearing at high as compared to low contextual positions.