Psycholinguistic mechanisms of classifier processing in sign language

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Abstract

Non-signers viewing sign language are sometimes able to guess the meaning of signs by relying on the overt connection between form and meaning, or iconicity (cf. Ortega et al., 2019; Strickland et al., 2015). One word class in sign languages that appears to be highly iconic, is classifiers: verb-like signs that can refer to location change, or handling. Classifier use and meaning is governed by linguistic rules, yet, in comparison with lexical verb signs, classifiers are highly variable in their morpho-phonology (variety of potential handshapes and motion direction within the sign). These open-class linguistic items in sign languages prompt the question about the mechanisms of their processing: are they part of gestural-semiotic system (processed like the gestures of non-signers), or are they processed as linguistic verbs? To examine the psychological mechanisms of classifier comprehension, we recorded EEG of signers, who watched videos of signed sentences with classifiers. We manipulated sentence word order of the stimuli (Subject-Object-Verb; SOV vs.

Object-Subject-Verb; OSV), contrasting the two conditions which, according to different processing hypotheses, should incur increased processing costs for OSV orders. As previously reported for lexical signs, we observed an N400 effect for OSV compared to SOV reflecting increased cognitive load for linguistic processing. These findings support the hypothesis that classifiers are a linguistic part of speech in sign language, extending current understanding of processing mechanisms at the interface of linguistic form and meaning.

Keywords: Austrian Sign Language, sign language processing, sign language classifiers, subject preference, ambiguity resolution

1. Introduction

Sign languages are natural, full-fledged, hierarchically structured languages, comparable in linguistic complexity to spoken languages, and exhibiting similar grammatical structures. Sign languages are expressed in the visual-manual modality using the three-dimensional signing space, i.e. the space in front of the signer, to convey linguistic information. In particular, sign languages are produced by manual (hands and arms) and non-manual (facial expressions and head/upper body positions/movements) means and are perceived by the visual system, in contrast to spoken languages, which are produced by the vocal tract and perceived by the auditory system.

In the present study we focus on Austrian Sign Language (abbreviated with "ÖGS").[1] ÖGS is the native language of about 8.000 Deaf people and has been officially accredited by law in Austria as a non-ethnical minority language in 2005.[2] However, the implementation of this legitimate foundation - involving accessible admission to community and education - has not taken place so far. For example, ÖGS is not the language of teaching and is not taught as a separate subject in Austrian Deaf schools (Dotter et al., 2019; Kramreiter & Krausneker, 2019). So far, relatively little is known about the syntactic structure of ÖGS and very few researchers have discussed data on ÖGS from a theoretical viewpoint (e.g. Wilbur, 2002, 2005; Schalber & Hunger, 2001, 2008; Schalber, 2006; Krebs et al., 2017) or investigated the neural processing of ÖGS (Krebs et al., 2018; Krebs, Malaia, Wilbur, & Roehm, 2019).

Despite the difference in modality, there are strong similarities between sign and spoken language processing: e.g both are processed by a fronto-temporal brain network within the dominant hemisphere (e.g. Corina & Spotswood, 2012; Emmorey, 2002 for an overview). In both sign and speech, different grammatical levels (e.g. syntax vs. semantics) draw on divergent brain mechanisms (e.g. Capek et al., 2009; Hänel-Faulhaber et al., 2014). However, modality does influence

[1] ÖGS is the abbreviation of the German translation of Austrian Sign Language: "Österreichische Gebärdensprache".
[2] Per convention *Deaf* with upper-case *D* refers to deaf or hard of hearing humans who define themselves as members of the sign language community. In contrast, *deaf* refers to audiological status.

neurocognitive processing of language in specific ways (for an overview see e.g. Campbell et al., 2007; Corina & Spotswood, 2012; Emmorey, 2002, 2007; MacSweeney et al., 2008). Recent advances in cross-modal research have shown that hearing non-signers without any sign language experience can infer aspectual meaning of signs using heuristic biases of event segmentation (Strickland et al., 2015), and that hearing persons who start to learn sign language can draw on experience with gesture when learning new signs (Ortega et al., 2019).

Sign languages have a class of words (signs) that appear to share properties of gesture and lexical signs: the classifiers. Classifiers provide means of referring back to an already mentioned referent using a pronominal form bound to the verb. Their categorizations may reflect particular grammatically-relevant semantic or physical features of noun referent classes (persons, animals, vehicles, long-thin things; Wilbur, Bernstein, & Kantor, 1985). The hand movement and/or the location of the constructions containing these classifier handshapes represent the verb component (Shepard-Kegl, 1985) and can be used to express the movements (events, activities) and/or locations (states) of the referents (in relation to other referents) the classifiers refer to (Frishberg, 1975). Some classifier handshapes may also have an agentive interpretation, showing handling information about an object (e.g. picking up something small and round). Thus, sign language handshape classifiers can be divided into two major categories: 1) the “whole entity classifiers”, with non-agentive interpretation; and 2) the “handling classifiers”, with agentive interpretation (Benedicto & Brentari, 2004). For ÖGS a similar classifier system and classifier categories, i.e. classifiers taking similar functions as those described for other sign languages, have been described as well (for more detailed information about ÖGS classifier handshapes and examples see Skant et al. (2002)).

The form and meaning of classifier signs tend to be overtly related, i.e. iconic. At the same time, classifiers differ from gesture in that they are linguistically controlled (governed by the internal rules of a specific sign language). For example, each sign language has a limited set of handshapes that may be used in classifiers; each sign language also determines a specific set of potential referents for a specific handshape. While non-signers use manual gestures which might look similar to sign language classifiers, gestures are not restricted in form and meaning in the same way that sign language classifiers are.

However, the linguistic status of sign language classifier constructions has been called into question (e.g. Cogill-Koez, 2000) because of the differences between conventional lexical signs and classifiers, manifested in two ways: 1) the high degree of meaning variability in classifier constructions, as opposed to lexical signs, and 2) the grammatical and iconic role of handshape in classifiers. The variability of meaning in classifier constructions is similar to that of pronouns: different classifiers can be used to represent one and the same entity, depending on which characteristic of an object is in focus. This many-classifiers-to-one-object relation is still, however, linguistically bound: the choice of a classifier is determined by the characteristics of the referent, discourse requirements, and phonological constraints (Wilbur et al., 1985). The grammatical status of the handshape, however, is what convinces many that classifiers are more similar to gesture than sign. In lexical signs, the handshape is learned as part of the sign, along with other phonological specifications (place of articulation and movement of a sign) and the sign's meaning (e.g. Lepic, 2015; Lepic et al., 2016; Padden et al., 2015). In contrast, the handshape of classifiers also functions as a meaningful unit – a morpheme. Classifiers allow for a wider range of handshapes to be assumed by the non-dominant hand, as compared to lexical signs (Emmorey, 2002); for example, in a two-handed classifier construction involving two objects, each handshape has a separate morphological status and bears independent referential meaning, while two-handed lexical items are restricted with respect to the handshapes the non-dominant hand can have (it can carry only phonological information even when providing a place of articulation as a base for articulation by the dominant hand) (Battison, 1978; Napoli & Wu, 2003; Malaia et al., 2017).[3]

[3] Signs consist also of non-manual components such as specific non-manual markings (e.g. specific brow or tongue position), and mouthing that describes a (part of a) spoken language word which is silently produced by the lips. These non-manual markings are expressed simultaneously to the manual components (e.g. Sandler & Lillo-Martin, 2006).

If classifiers are not processed as linguistic items by signers, the alternative that might account for classifier comprehension as gesture would be the gestural-semiotic processing strategy (Ortega et al., 2019). When the function of the classifier construction is to locate two referents with respect to each other (relative location of each), the resulting structures are often described as showing Figure-Ground relations, with the Figure referring to the “locative subject” and the Ground referring to the “locative object”. Traditionally in Figure-Ground constructions, the figure is the more mobile of the two, although if both are equally mobile (e.g. two humans), then the figure is taken to be the one in focus (Liddell, 1980 for American Sign Language ASL; Coerts, 1994 for the Sign Language of the Netherlands NGT). Two semantic factors relevant to use of the Figure-Ground strategy in comprehension are mobility and animacy. Immobile, mostly bigger objects tend to be introduced first as Ground, and mobile, often smaller referents represent Figures and are produced later.

The question of whether classifier comprehension relies on linguistic processing or on a non-linguistic gestural-semiotic processing strategy is relevant to multiple processing theories concerned with the relationship between cognition and language acquisition. If classifiers are processed as linguistic by Deaf signers, this would indicate high flexibility of the processing mechanism at the syntax-semantics-phonology interface, which can account for open-class items like classifiers via parallel processing. If, on the other hand, signers use non-linguistic semiotic resources to understand the meaning of classifiers, it would suggest reliance on a general cognitive processing strategy which can be used by those learning sign language for the first time (cf. Ortega et al., 2019).

Neural indices in comparison of linguistic vs. gestural articulation

While there is a paucity of EEG studies that consider sign language word classes, there are several L2 (sign language learning) studies that investigated the neural processing of gestures and signs (cf. Ortega et al., 2019; Ibáñez et al., 2010). Ortega et al. (2019) investigated the effect of visual similarity to typical gestures on sign learning, concluding that it was a primary driver of observed differences in neural processing. In this study hearing non-signers were presented with iconic signs either showing high or low overlap with iconic gestures. The novelty-driven P300 effect was expected for signs showing low overlap with iconic gestures in comparison to signs showing high overlap with gestures. The P300 is related to cognitive processes of decision-making, stimulus categorization and context-updating (Picton, 1992; Donchin & Coles, 1988): its' amplitude increases for task-relevant, salient, informative, and improbable stimuli (Polich, 2004) and it may also index (dis)confirmed expectations about upcoming stimuli (Roehm et al., 2007; Van Petten & Luka, 2012). Ortega et al. (2019) observed the modality-independent anteriorly-distributed version of the P300 effect (P3a effect typically observed for novel stimuli; Friedman et al., 2001; Polich, 2007) for signs with low overlap with iconic gestures compared to signs with high overlap with gestures (when the participants were exposed to the signs for the first time). This general novelty-driven effect between gesturally familiar and unfamiliar signs, however, diminished with exposure of learners to the signs, disappearing after a training session. Ortega et al. (2019) conclude that non-signers activate their gestural knowledge when generating expectations about the form of signs and that learners draw on any available semiotic resources (i.e. not only on their linguistic experience) when acquiring a second language.

The ERP component that is known to respond to unpredicted information or information that was not pre-activated on the basis of previous processing steps is the N400. It is a broadly-distributed, negative-going component peaking around 400 milliseconds post-word-onset, the amplitude of which is sensitive to a number of linguistic parameters. One of these parameters is word frequency; familiar, but rare word forms elicit a stronger N400 as compared to more frequently-used lexical items (Van Petten & Kutas, 1990). The N400 is also sensitive to any type of linguistic priming - its amplitude is reduced when a target word is preceded by a semantically, morphologically, or orthographically similar word (in the same language, or a different one). Ortega et al. (2019) originally hypothesized an N400 effect for signs with low overlap with gestures compared to signs with high overlap with gestures; or, alternatively, a reduced N400 would be identified for signs with high gestural overlap due to processing ease. Ortega et al. (2019) did not observe an N400 effect for sign learners (when first exposed to signs as well as after a training session). The authors suggested that the form-meaning mapping in the acquisition of a second language in sign might be facilitated by iconicity.

In a sentence context, sources of an N400 include mismatch in meaning (Kallioinen et al., 2016; Baggio & Hagoort, 2011), as well as re-analysis due to local ambiguity resolution, such as argument role re-assignment in garden-path sentences (Osterhout et al., 1994; Malaia et al., 2009; Philipp et al., 2008). Another parameter that can strongly influence the N400 amplitude to a word in a sentence context is cloze probability. Cloze probability is the likelihood of the target word completing the specific sentence frame in which it occurs – in other words, linguistic unexpectedness of word use given a specific sentence structure. Kutas and Hillyard (1984) demonstrated that the use of an unexpected word in a sentence results in an increased N400 relative to more expected words. Overall, the N400 effect is reliably observed in sentence context in response to those words, which trigger re-processing of previous linguistic material, whether with regard to their semantics (meaning) or syntax (word order, or thematic role assignment). This particular property of the N400 ERP component was relied on in the experimental design of the present study.

The present study

The present study focused on identifying the neural processing mechanism employed by proficient signers for comprehension of sentences with classifiers. We asked whether classifier constructions are processed as lexical verbs (showing interactions with other linguistic phenomena), or like spatial gestures. Stimuli sentences contained classifier constructions which indicated a spatial relationship between two arguments. The arguments used in the sentences belonged to the same semantic class, such that the classifier handshape could refer to either of the arguments. After the arguments were indexed in space, the direction of classifier motion disambiguated which argument moved towards which one (i.e. which argument could be semiotically interpreted as the Figure and which as the Ground, or between the active and the passive argument). Thus, the direction of classifier motion also disambiguated the syntactic structure of the sentence: it identified whether the word order of the sentence was Subject-Object-Verb (SOV), with the Agent indexed first, and Patient indexed second, or Object-Subject-Verb (OSV), with the Patient indexed first and the Agent indexed second. The basic sign order of ÖGS is SOV (Skant et al., 2002; Wilbur, 2002, 2005), although in the context of agreeing verbs and plain verbs that are accompanied by an agreement marker, OSV orders are acceptable (Krebs et al., 2018; Krebs, Wilbur, Alday, & Roehm, 2019). The subject-first strategy (i.e. the subject preference) has been observed for sign and spoken languages (Krebs et al., 2018; Krebs, Wilbur, Alday, & Roehm, 2019; Krebs, Malaia, Wilbur, & Roehm, 2019; Haupt et al., 2008; Wang et al., 2009).

The experimental design contrasts two hypotheses about possible processing strategies for classifier predicates. First, if classifier processing is governed by linguistic (syntactic) rules in the same manner that is evident in the processing of lexical signs, then classifiers in the sentence-final position would be processed differently depending on whether the word order in the sentence is SOV or OSV. In this case, we would expect a subject preference-driven broadly distributed N400 effect for OSV word order due to local ambiguity resolution at the point of classifier predicate onset (similar to the one observed for lexical verb signs). Subject preference effects on behavioral data, such as acceptability ratings or response times, can be subtle in either sign or spoken languages, even when neural processing differences manifest clear effects (Krebs et al., 2018; Malaia et al., 2009). For this reason, we did not expect to find significant differences between SOV and OSV conditions in acceptability ratings or response times.

The alternative hypothesis is predicated on the findings that overt form-to-meaning mapping facilitates sign processing (Ortega et al., 2019). If classifier comprehension does not depend on the syntactic structure of the sentence, i.e. if classifiers are processed using a gestural-semiotic mapping, no subject preference effect (the N400 effect) is expected for OSV compared to SOV sentences. As spatial gestures would not be expected to interact with linguistic phenomena manipulated in the experiment (processing of word order variation and resolution of a locally ambiguous argument structure), an absence of the N400 effect for OSV as compared with SOV condition would indicate that visual-spatial form-to-meaning mapping prevails over a linguistic processing strategy in classifier predicate comprehension. The two hypotheses and their predictions are summarized in Table 1:

[Please insert Table 1 here]

2. Method

2.1. Experiment Design

We presented participants with videos of signed classifier constructions in ÖGS in which we manipulated the word order (either SOV or OSV). A set of 40 sentences were presented in each condition (SOV or OSV). To avoid strategic processing, filler sentences were additionally included in the experiment leading for a total of 280 videos. The fillers consisted of (a) SOV and OSV sentences containing agreeing verbs, with or without topic marking on the first argument (n = 160), and (b) ÖGS videos presented in reversed video-frame order (n = 40). The reversed videos were included to ensure the reliability of the participants' ratings, i.e. to check whether the subjects understood and correctly completed the ratings task. The constructions involved only non-compound, frequent signs (the arguments MAN, WOMAN, GIRL and BOY were used in the sentences). All the stimuli were signed by a right-handed Deaf woman who acquired ÖGS early in life, teaches ÖGS, uses ÖGS in her daily life and is a member of the Deaf community.[4]

[4] Within the video material the background color as well as the light conditions were kept constant among conditions.

2.2. Stimuli

In the classifier constructions both arguments were referenced by the same whole entity classifier within one sentence (i.e. either the classifier for a sitting or a standing person), to ensure that only the direction of classifier motion allowed to disambiguate between thematic roles of the arguments. The use of identical classifier handshapes in one sentence ensured that both arguments were equally likely to represent the active referent within the sentence. The same arguments were used within one sentence to avoid any semantic biases (e.g. The man moves towards another man). To create the 40 sentences for each condition and use only the two classifier handshapes (for sitting or standing person), we varied the spatial distance between the arguments (little vs. more distance between referents) as well as their orientation with respect to each other (sitting/standing opposite to each other vs. next to each other). The sentence-initial argument was always referenced at the left side of the signer.[5] After the arguments were referenced in space, the classifier predicate indicated the movement of one of the referents, who either walked, jumped with small successive jumps or jumped with one big jump towards or away from the other referent.[6] Thus, either the classifier referencing the first argument indicated motion in relation to the argument referenced second (in SOV orders) or the classifier referencing the second argument indicated motion in relation to the argument referenced first (in OSV orders) (Figure 1). At the end of the movement of the active referent, the active referent either stood beside/opposite the other (passive) referent or sat beside/opposite/in front of or behind the other referent (see Appendix I for the list of nouns and verbs used in the study).

[insert Figure 1 here]

[5] Note that at the moment there is no evidence of any default referencing (i.e. in that subjects are always referenced at the ipsi- or contralateral side of the signer) in ÖGS.
[6] In ÖGS discourse referents can also be located in signing space by manual index/pointing signs as well as by non-manual cues (e.g. body shift and/or eye gaze towards a specific location in space).

2.3. Participants

From the 25 persons who participated, 20 (9 females) were included in the final analysis (age *M*=39.37, *SD* = 10.19; range 28 to 58). Four participants were excluded due to EEG artifacts (less than 70% of critical trials remaining after artifact rejection; one participant was excluded due to behavioral noncompliance (giving high acceptability ratings to reversed videos). All participants were born Deaf or lost their hearing early in life. Three have Deaf parents, the others hearing parents. Half acquired sign language starting between 4-7 years, five participants between 0-3 years, and five subjects at a later age: one signer between 13-17 years, another between 18-22 years and three after the age of 22. Participants came from different areas of Austria (Salzburg, Vienna, Upper Austria, Lower Austria, Styria). Language proficiency of all participants was confirmed by a professional ÖGS interpreter during the informed consent procedure. Informed consent was obtained in written form by a certified interpreter in accordance with the declaration of Helsinki. Fifteen participants were right-handed, four left-handed and one did not have a dominant hand preference (tested by an adapted German version of the Edinburgh Handedness Inventory; Oldfield, 1971). At the time of the study none showed any neurological or psychological disorders. All had normal or corrected vision and were not influenced by medication or other substances which may impact cognitive ability.

2.4. Procedure

The videos (sized 35.3 x 20 cm) were presented on the computer screen, while the participant sat 1 meter away from it. The material was presented in 14 blocks, each containing 20 sentences. Every trial started with the presentation of a fixation cross, which remained on the screen for 2000 ms, and was followed by an empty black screen for 200 ms. A stimulus sentence (video) was then presented in the middle of the screen. Each trial ended with a rating task, while a green question mark remained on the screen for 3000 ms after each stimulus. Participants had to rate the videos on a scale from 1 to 7, indicating whether, in their opinion, the stimulus was an acceptable ÖGS sentence (1 stood for ‘that is not ÖGS’; 7 stood for ‘that is good ÖGS’). Ratings were given by button-press on a keyboard. Prior to the experiment, a training block of sentences was presented to familiarize participants with task requirements and permit them to ask questions. The duration of breaks after each block was determined by the participants’ wishes.

2.5. EEG recording

The EEG was recorded from twenty-six electrodes (Fz, Cz, Pz, Oz, F3/4, F7/8, FC1/2, FC5/6, T7/8, C3/4, CP1/2, CP5/6, P3/7, P4/8, O1/2) fixed on the participant’s scalp by an elastic cap (Easy Cap, Herrsching-Breitbrunn, Germany). Horizontal eye movements (HEOG) were registered by electrodes at the lateral ocular muscles and vertical eye movements (VEOG) were recorded by electrodes fixed above and below the left eye. All electrodes were referenced against the electrode on the left mastoid and re-referenced later offline to the average of left and right mastoids. The AFz electrode functioned as the ground. EEG signal was recorded using a Brain Products amplifier (high pass 0.01Hz) with a sampling rate of 500 Hz; electrode impedances were kept below 5 kΩ.

2.6. Data analysis

2.6.1. Behavioral data

Acceptability ratings and reaction times per participant (subject) and per item were assessed using repeated-measures ANOVA. The fixed factor ORDER (SOV vs. OSV) and the random factors SUBJECTS (F_{Subj}) and ITEMS (F_{Item}) were included. Absent or late responses were not counted. The statistical analysis was carried out hierarchically; only significant interactions ($p \leq 0.05$) were resolved using a step-down approach.

2.6.2. ERP data

The signal was corrected for ocular artifacts using the Gratton and Coles method (Gratton et al., 1983) and screened for artifacts (minimal/maximal amplitude at -75/+75 µV). Raw EEG signal was bandpass-filtered (Butterworth Zero Phase Filters; high pass: 0.1 Hz, 48 dB/Oct; low pass: 20 Hz, 48 dB/Oct). Data was baseline-corrected to -300 to 0. The percentage of trials remaining after artifact rejection (per condition at the time/first frame at which the hand referencing the subject started to move) are presented in Table 2. Participants were excluded from analysis if less than 70% of the critical trials remained after artifact rejection.

Statistical analysis of the ERP data compared mean amplitudes per time window per condition per subject in six lateral regions of interest (ROIs) and in three midline electrodes (MID). ROIs included the following electrodes: anterior left = F7, F3, FC5; anterior right = F8, F4, FC6; central left = FC1, CP5, CP1; central right = FC2, CP6, CP2; posterior left = P7, P3, O1 and posterior right = P8, P4, O2. The factor MID included three electrodes: Fz, Cz and Pz. The statistical analysis was carried out in a hierarchical manner, i.e. only significant interactions ($p \leq 0.05$) were resolved. For the statistical analysis of the ERP data an ANOVA was computed including the factor of condition ORDER (SOV vs. OSV) and the factors ROI or MID. To correct for violations of sphericity, the Greenhouse-Geisser (1959) correction was applied to repeated measures with greater than one degree of freedom.

[insert Table 2 here]

3. Results

3.1. Behavioral data

Acceptability ratings. Sentences with both SOV and OSV orders were rated high in acceptability (at least 5.67 on a scale from 1 to 7). Acceptability ratings for the two critical conditions did not differ significantly from each other [$F_{subj}(1, 19) = 1.23$; $p = 0.28$; $F_{item}(1, 19) = 2.25$; $p = 0.14$]. Mean acceptability ratings for the reversed-video filler condition (*mean* = 1.70; *sd* = 0.83) differed significantly from both the mean acceptability ratings for the SOV stimuli [$F_{subj}(1, 19) = 255.85$; $p < 0.001$] and the OSV stimuli [$F_{subj}(1, 19) = 252.71$; $p < 0.001$].

Reaction times. The mean reaction times for stimuli did not differ significantly [$F_{subj}(1, 19) = 2.49$; $p = 0.13$; $F_{item}(1, 19) = 2.46$; $p = 0.13$]. Mean reaction time for the reversed-video filler condition (*mean* = 909.34; *sd* = 446.39) did not differ significantly from the mean reaction times for classifier sentences ($F < 1$).

Table 3 provides an overview of the acceptability ratings and reaction times for both critical conditions (SOV and OSV). These were also compared with acceptability rating and reaction times for the reversed-video fillers. Only significant effects ($p \leq 0.05$) are reported.

[insert Table 3 here]

3.2. ERP data

The first frame of the hand movement for the disambiguating classifier predicate was time-stamped as the onset of disambiguating motion. A pronounced negativity for OSV as compared to SOV word order was observed in the 300 to 800 ms time window (Figure 2). Statistical analysis revealed a significant main effect of ORDER for lateral ROIs [$F(1, 19) = 10.69$, $p < 0.01$, $\eta_p^2 = 0.36$], as well as a significant main effect of ORDER for MID electrodes [$F(1, 19) = 10.44$, $p < 0.01$, $\eta_p^2 = 0\ .35$]. Significant interactions, ORDER x ROI [$F(5, 95) = 6.01$, $p < 0.01$, $\eta_p^2 = 0.24$] and ORDER x MID [$F(2, 38) = 4.07$, $p < 0.05$, $\eta_p^2 = 0.18$] were also observed. The resolution of the interaction ORDER x ROI revealed significant ORDER effects in the right anterior [$F(1, 19) = 9.88$, $p < 0.01$, $\eta_p^2 =$

0.34], left central [$F(1, 19) = 8.08$, $p < 0.05$, $\eta_p^2 = 0.30$], right central [$F(1, 19) = 13.42$, $p < 0.01$, $\eta_p^2 = 0.41$] and right posterior [$F(1, 19) = 26.03$, $p < 0.001$, $\eta_p^2 = 0.58$] ROIs. The resolution of the interaction ORDER x MID revealed a significant effect at the anterior [$F(1, 19) = 9.61$, $p < 0.01$, $\eta_p^2 = 0.34$], central [$F(1, 19) = 6.98$, $p < 0.05$, $\eta_p^2 = 0.27$] and posterior [$F(1, 19) = 12.30$, $p < 0.01$, $\eta_p^2 = 0.39$] midline electrodes.[7] Only significant ERP effects ($p \leq 0.05$) are reported.

The ERP data analysis revealed a significant negative ERP effect for OSV compared to SOV orders. This finding supports the hypothesis that the classifier sentences examined in the present study are not processed via a gestural-semiotic strategy by signers. Instead, the data support the hypothesis that sign language classifiers are processed in the manner that is similar to that in which lexical verbs are processed in sign language – i.e. that their structure is linguistically controlled.

[insert Figure 2 here]

4. Discussion

We investigated the neural mechanisms underlying processing strategies for classifiers – a part of speech unique to sign languages, which has both linguistic and gestural characteristics. The experimental design – use of sentences with classifiers that expressed the spatial relationship between two human referents - aimed to create an ambiguity that could be resolved by either of the two processing mechanisms (linguistic vs. gestural-semiotic). The behavioral data did not show any preference for one or the other word order in acceptability ratings, suggesting that we successfully created truly ambiguous and equally acceptable stimuli for both conditions. While reaction times did

[7] That the observed effect was not driven by the inclusion of five late learners was shown by an additional ERP data analysis excluding the five late learners. This analysis revealed a significant main effect of ORDER for ROI [$F(1, 14) = 6.52$, $p < 0.05$, $\eta_p^2 = 0.32$] and a significant main effect of ORDER for MID [$F(1, 14) = 5.75$, $p < 0.05$, $\eta_p^2 = 0.29$]. In addition, a significant interaction ORDER x ROI [$F(5, 70) = 8.75$, $p < 0.001$, $\eta_p^2 = 0.38$] and a significant interaction ORDER x MID [$F(2, 28) = 6.46$, $p < 0.01$, $\eta_p^2 = 0.32$] was observed. The resolution of the interaction ORDER x ROI revealed significant ORDER effects in the right anterior [$F(1, 14) = 5.50$, $p < 0.05$, $\eta_p^2 = 0.28$], right central [$F(1, 14) = 11.06$, $p < 0.01$, $\eta_p^2 = 0.44$] and right posterior [$F(1, 14) = 27.13$, $p < 0.001$, $\eta_p^2 = 0.66$] ROIs. The resolution ORDER x MID revealed a significant effect at the anterior [$F(1, 14) = 5.43$, $p < 0.05$, $\eta_p^2 = 0.28$] and posterior [$F(1, 14) = 8.21$, $p < 0.05$, $\eta_p^2 = 0.37$] midline electrodes.

not differ between conditions, online EEG data from Deaf signers revealed a pattern of processing for classifiers that was indicative of linguistic, rather than gestural-semiotic processing. The ERP analysis indicated enhanced processing costs (i.e. a broadly distributed N400 effect) for OSV (Patient-first) word order compared to SOV (Agent-first) word order, which we interpret as a reflection of the subject-first processing strategy that was reported previously for sign and spoken languages (Haupt et al., 2008; Wang et al., 2009; Krebs et al., 2018; Krebs, Malaia, Wilbur, & Roehm, 2019).

Classifier processing mechanisms are a particularly interesting phenomenon from the standpoint of both psychological models and linguistic theory, because classifiers as a part of speech straddle the divide between purely linguistic signs in the visual-manual modality, and semantically meaningful gesture. Understanding of how classifiers are processed by native and non-native signers bears on a larger question of the interface between perception, language and cognition.

In theoretical linguistic research, the observation that most sign languages with locative classifiers show a preference towards a locative object / locative subject / locative predicate order (OSV)-order (despite their different basic sign orders) has led some researchers to suggest that this preference is not linguistically governed but is rather driven by the visual-manual modality. Kimmelman (2012) points out that hearing non-signers use the same locative object / locative subject / locative predicate order when describing pictures expressing locative events nonverbally (pantomime/gesture), suggesting a cognitive 'mental map' approach to these relationships when using spatial/visual means of expression. Hearing non-signers also prefer animate/agent arguments in sentence-initial position, suggesting a modality-independent preference for what makes a good subject and how it should be expressed (e.g. Hall et al., 2013; Laudanna & Volterra, 1991; Meir et al., 2017).

The claim that classifier signs are complex linguistic constructions is further supported by neuroimaging data, which indicates that language-specialized brain areas in the left hemisphere are involved during classifier processing (e.g. Emmorey et al., 2013; Hickok et al., 2009; Newman et al., 2015). A number of studies on native signers, however, have also suggested that sign language classifiers are processed somewhat differently from lexical signs (e.g. Emmorey et al., 2002, 2005, 2013; 2014; MacSweeney et al., 2002; McCullough et al., 2012). Neuroimaging and lesion studies suggest that the processing of classifiers engages spatial-processing networks in the right hemisphere and in bilateral parietal brain areas to a greater extent than processing of lexical signs (e.g. Atkinson, et al. 2004, 2005; Hickok et al., 1999, 2009; Poizner et al., 1987; Emmorey et al., 2002, 2005, 2013, 2014; MacSweeney et al., 2002). Whether this evidence reflects enhanced (non-linguistic) visual-spatial processing, or whether it shows "spatially-based syntactic processing" is still an open question.

Multiple neurophysiological and behavioral studies indicated that the subject preference processing strategy - the tendency to interpret the sentence-initial argument as the subject - elicits a reliable broadly distributed reanalysis N400 effect in spoken and sign languages (e.g. Haupt et al.,2008; Wang et al., 2009; Krebs et al., 2018; Krebs, Malaia, Wilbur, & Roehm, 2019). The subject preference has also been described in terms of actor preference, whereby the actor is understood as the participant primarily responsible for the state of affairs that is described by the event (cf. proto-Agents in Primus, 1999; Malaia, Wilbur, & Weber-Fox, 2012, 2013), which yields similar re-analysis and disambiguation effects in neural data (e.g. Alday et al., 2014; Bornkessel & Schlesewsky, 2006; Bornkessel-Schlesewsky & Schlesewsky, 2009, 2013). Our results support and extend the observation that the subject preference is a preferred processing strategy of ÖGS, whether driven by syntactic word order, or semantic parameters of arguments, such as animacy, or both.

One of the limitations of the study is that we did not test for the effect of animacy on argument processing in sentences with classifiers. Argument animacy has also been shown to interact with thematic role assignment at early stages of processing (Malaia & Newman, 2015a, b). For other sign languages it has been shown that animacy can cancel out a Figure-Ground interpretation (Volterra et al., 1984), so that animate (i.e. most agent-like) arguments are preferred in sentence-initial position, i.e. before inanimate arguments, even in locative constructions (e.g. Coerts, 1994; Leeson, 2001; Kimmelman, 2012). It is, thus, possible that a combination of animate and inanimate arguments in the sentence might change the online processing strategy - it would be interesting to test whether the subject preference could be overridden by the Figure-Ground principle in sentences with inanimate arguments for which a Figure-Ground relation can be clearly established (e.g. a big/immobile vs. a small/mobile referent).

5. Conclusion

The present study revealed an N400 reanalysis effect for sentences with OSV word order (in contrast to SOV) containing classifiers. This data indicates a linguistic, rather than a spatial gestural-semiotic processing strategy for sign language classifiers: locally ambiguous classifier constructions are processed using a linguistic strategy in transitive sentences (Krebs, 2017; Krebs, et al., 2018; Krebs, Wilbur, Alday, & Roehm, 2019; Krebs, Malaia, Wilbur, & Roehm, 2019). We show that the high iconicity of sign language classifiers does not affect processing mechanisms during ambiguity resolution/argument structure assignment for Deaf signers: in sign language, locative classifier constructions are linguistically controlled constructions rather than suggested partially non-linguistic gesture. These findings suggest that further work investigating how classifiers are acquired by signing children, can be instrumental in understanding interconnected development of language and cognition in the visuo-spatial modality.

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Conflict of Interest Statement

The authors report no conflicts of interest.

References

Alday, P. M., Schlesewsky, M., & Bornkessel-Schlesewsky, I. (2014). Towards a computational model of actor-based language comprehension. *Neuroinformatics*, 12, 143–179. doi: 10.1007/s12021-013-9198-x

Atkinson, J., Campbell, R., Marshall, J., Thacker, A., & Woll, B. (2004). Understanding 'not': Neuropsychological dissociations between hand and head markers of negation in BSL. *Neuropsychologia*, 42, 214-229. doi: 10.1016/S0028-3932(03)00186-6

Atkinson, J., Marshall, J., Woll, B., & Thacker, A. (2005). Testing comprehension abilities in users of British Sign Language following CVA. *Brain and Language*, 94, 233-248. doi: 10.1016/j.bandl.2004.12.008

Baggio, G., & Hagoort, P. (2011). The balance between memory and unification in semantics: A dynamic account of the N400. *Language and Cognitive Processes, 26*(9), 1338-1367.

Battison, R. (1978). *Lexical borrowing in American Sign Language*. Silver Spring: Linstok Press.

Benedicto, E., & Brentari, D. (2004). Where did all the arguments go?: Argument-changing properties of classifiers in ASL. *Natural Language & Linguistic Theory*, 22, 743-810. doi: 10.1007/s11049-003-4698-2

Bornkessel-Schlesewsky, I., & Schlesewsky, M. (2009). The role of Prominence information in the real-time comprehension of transitive constructions: A cross-linguistic approach. *Language and Linguistics Compass*, 3, 19–58. doi: 10.1111/j.1749-818X.2008.00099.x

Bornkessel-Schlesewsky, I., & Schlesewsky, M. (2013). Reconciling time, space and function: A new dorsal–ventral stream model of sentence comprehension. *Brain and Language*, 125, 60–76. doi: 10.1016/j.bandl.2013.01.010

Bornkessel, I., & Schlesewsky, M. (2006). The extended argument dependency model: A neurocognitive approach to sentence comprehension across languages. *Psychological Review*, 113, 787–821. doi: 10.1037/0033-295X.113.4.787

Campbell, R., MacSweeney, M., & Waters, D. (2007). Sign language and the brain: A Review. *The Journal of Deaf Studies and Deaf Education, 13*, 3-20. doi: 10.1093/deafed/enm035

Capek, C. M., Grossi, G., Newman, A. J., McBurney, S. L., Corina, D., Roeder, B., & Neville, H. J. (2009). Brain systems mediating semantic and syntactic processing in deaf native signers: Biological invariance and modality specificity. *Proceedings of the National Academy of Sciences of the United States of America (PNAS), 106*, 8784-8789. doi: 10.1073/pnas.0809609106

Coerts, J. (1994). Constituent order in sign language of the Netherlands. In M. Brennan & G. H. Turner (Eds.), *Word order issues in Sign Language: Working papers (presented at a workshop held in Durham 18-22 September 1991)* (pp. 47-71). Durham: International Sign Linguistics Association (ISLA).

Cogill-Koez, D. (2000). Sign language classifier predicates: Linguistic structures or schematic visual representation? *Sign language & Linguistics, 3*, 153-207. doi: 10.1075/sll.3.2.03cog

Corina, D. P., & Spotswood, N. (2012). Neurolinguistics. In R. Pfau, M. Steinbach & B. Woll (Eds.), *Sign language. An international handbook* (pp. 739-762). Berlin: Mouton de Gruyter.

Donchin, E., & Coles, M. G. H. (1988). Is the P300 component a manifestation of context-updating? *Behavioral and Brain Sciences, 11*, 355-372.

Dotter, F., Krausneker, V., Jarmer, H., & Huber, L. (2019). Austrian Sign Language: Recognition Achieved but Discrimination Continues. In: M. De Meulder, J. J. Murray, & R. McKee (Eds.), *The Legal Recognition of Sign Languages: Advocacy and Outcomes Around the World* (pp. 209-223). Bristol: Multilingual Matters.

Emmorey, K. (2002). *Language, cognition, and the brain. Insights from sign language research*. Mahwah, New Jersey: Lawrence Erlbaum Associates.

Emmorey, K. (2007). The psycholinguistics of signed and spoken languages: How biology affects processing. *The Oxford handbook of psycholinguistics,* 703-721. doi: 10.1093/oxfordhb/9780198568971.013.0043

Emmorey, K., Damasio, H., McCullough, S., Grabowski, T., Ponto, L. L. B., Hichwa, R., & Bellugi, U. (2002). Neural systems underlying spatial language in American Sign Language. *Neuroimage, 17*, 812-824. doi: 10.1006/nimg.2002.1187

Emmorey, K., Grabowski, T., McCullough, S., Ponto, L. L., Hichwa, R. D., & Damasio, H. (2005). The neural correlates of spatial language in English and American Sign Language: a PET study with hearing bilinguals. *Neuroimage, 24*, 832-840. doi: 10.1016/j.neuroimage.2004.10.008

Emmorey, K., McCullough, S., Mehta, S., Ponto, L. L., & Grabowski, T. J. (2013). The biology of linguistic expression impacts neural correlates for spatial language. *Journal of Cognitive Neuroscience, 25*, 517-533. doi: 10.1162/jocn_a_00339

Emmorey, K., McCullough, S., Mehta, S., & Grabowski, T. J. (2014). How sensory-motor systems impact the neural organization for language: direct contrasts between spoken and sign language. *Frontiers in psychology, 5*, 1-13. doi: 10.3389/fpsyg.2014.00484

Friedman, D., Cycowicz, Y. M., & Gaeta, H. (2001). The novelty P3: An event-related brain potential (ERP) sign of the brain's evaluation of novelty. Neuroscience and Biobehavioral Reviews, 25, 355–373. http://dx.doi.org/10.1016/S0149-7634(01)00019-7

Frishberg, N. (1975). Arbitrariness and iconicity: Historical change in American Sign Language. *Language, 51,* 696-719. doi: 10.2307/412894

Gratton, G., Coles, M. G., & Donchin, E. (1983). A new method for off- line removal of ocular artifact. *Electroencephalography and clinical neurophysiology, 55*, 468-484. doi:10.1016/0013-4694(83)90135-9

Greenhouse, S. W., & Geisser, S. (1959). On methods in the analysis of profile data. *Psychometrika, 24*, 95-112. doi: 10.1007/bf02289823

Hall, M. L., Mayberry, R. I., & Ferreira, V. S. (2013). Cognitive constraints on constituent order: Evidence from elicited pantomime. *Cognition, 129,* 1-17. doi: 10.1016/j.cognition.2013.05.004

Hänel-Faulhaber, B., Skotara, N., Kügow, M., Salden, U., Bottari, D., & Röder, B. (2014). ERP correlates of German Sign Language processing in deaf native signers. *BMC Neuroscience*, *15*, 1-11. doi: 10.1186/1471-2202-15-62

Haupt, F. S., Schlesewsky, M., Roehm, D., Friederici, A. D., & Bornkessel-Schlesewsky, I. (2008). The status of subject-object reanalyses in the language comprehension architecture. *Journal of Memory and Language*, *59*, 54-96. doi:10.1016/j.jml.2008.02.003

Hickok, G., Wilson, M., Clark, K., Klima, E. S., Kritchevsky, M., & Bellugi, U. (1999). Discourse deficits following right hemisphere damage in deaf signers. *Brain and Language, 66,* 233-348. doi: 10.1006/brln.1998.1995

Hickok, G., Pickell, H., Klima, E. S., & Bellugi, U. (2009). Neural dissociation in the production of lexical versus classifier signs in ASL: Distinct patterns of hemispheric asymmetry. *Neuropsychologia, 47*, 382-387. doi: 10.1016/j.neuropsychologia.2008.09.009

Ibáñez, A., Manes, F., Escobar, J., Trujillo, N., Andreucci, P., & Hurtado, E. (2010). Gesture influences the processing of figurative language in non-native speakers: ERP evidence. *Neuroscience Letters*, 471(1), 48-52.
Kallioinen, P., Olofsson, J., Nakeva von Mentzer, C., Lindgren, M., Ors, M., Sahlén, B. S., ... & Uhlén, I. (2016). Semantic processing in deaf and hard-of-hearing children: Large N400 mismatch effects in brain responses, despite poor semantic ability. *Frontiers in psychology*, 7, 1146.
Kimmelman, V. (2012). Word order in Russian Sign Language. *Sign Language Studies, 12*, 414-445. doi: 10.1353/sls.2012.0001
Kramreiter, S., & Krausneker, V. (2019). Bilingual, inclusive, mixed-age schooling in Vienna. In: M. Marschark, S. Antia, & H. Knoors (Eds.), *Co-Enrollment for Deaf Learners* (pp. 133-147). New York: Oxford University Press.
Krebs, J. (2017). *The syntax and the processing of argument relations in Austrian Sign Language (ÖGS)* (Doctoral dissertation). University of Salzburg, Salzburg, Austria.
Krebs, J., Wilbur, R. B. & Roehm, D. (2017). Two agreement markers in Austrian Sign Language (ÖGS). *Sign Language and Linguistics*, 20, 27-54. doi: 10.1075/sll.20.1.02kre issn 1387-9316
Krebs, J., Malaia, E., Wilbur, R.B. & Roehm, D. (2018). Subject preference emerges as cross-modal strategy for linguistic processing. *Brain Research*, 1691, 105-117. doi: 10.1016/j.brainres.2018.03.029
Krebs, J., Wilbur, R. B., Alday, P. M., & Roehm, D. (2019). The impact of transitional movements and non-manual markings on the disambiguation of locally ambiguous argument structures in Austrian Sign Language (ÖGS). *Language and Speech*, *62*, 652-680. doi: 10.1177/0023830918801399
Krebs, J., Malaia, E., Wilbur, R. B., & Roehm, D. (2019). Interaction between topic marking and subject preference strategy in sign language processing. *Language, Cognition and Neuroscience*, 1-19. doi: 10.1080/23273798.2019.1667001
Kutas, M., & Hillyard, S. A. (1984). Brain potentials during reading reflect word expectancy and semantic association. *Nature*, 307(5947), 161-163.
Laudanna, A., & Volterra, V. (1991). Order of words, signs, and gestures: A first comparison. *Applied Psycholinguistics, 12*, 135-150. doi: 10.1017/s0142716400009115
Leeson, L. (2001). *Aspects of verbal valency in Irish Sign Language* (Unpublished doctoral dissertation). University of Dublin, Trinity College, Dublin, Ireland.
Lepic, R. (2015). *Motivation in morphology: Lexical patterns in ASL and English* (Doctoral dissertation). Retrieved from https://escholarship.org.
Lepic, R., Börstell, C., Belsitzman, G., & Sandler, W. (2016). Taking meaning in hand. *Sign Language & Linguistics, 19*, 37-81. doi: 10.1075/sll.19.1.02lep
Liddell, S. K. (1980). *American Sign Language syntax*. The Hague: Mouton de Gruyter.
MacSweeney, M., Woll, B., Campbell, R., Calvert, G. A., McGuire, P. K., David, A. S., Simmons, A., Brammer, M. J. (2002). Neural correlates of British Sign Language comprehension: Spatial processing demands of topographic language. *Journal of Cognitive Neuroscience, 14,* 1064-1075. doi: 10.1162/089892902320474517
MacSweeney, M., Capek, C. M., Campbell, R., & Woll, B. (2008). The signing brain: the neurobiology of sign language. *Trends in cognitive sciences, 12*, 432-440. doi: 10.1016/j.tics.2008.07.010
Malaia, E., Wilbur, R. B., & Weber-Fox, C. (2009). ERP evidence for telicity effects on syntactic processing in garden-path sentences. *Brain and language, 108*(3), 145-158.
Malaia, E., Wilbur, R. B., & Weber-Fox, C. (2012). Effects of verbal event structure on online thematic role assignment. *Journal of psycholinguistic research*, 41(5), 323-345.
Malaia, E., Wilbur, R. B., & Weber-Fox, C. (2013). Event end-point primes the undergoer argument: Neurobiological bases of event structure processing. In *Studies in the composition and decomposition of event predicates* (pp. 231-248). Springer, Dordrecht.

Malaia, E., & Newman, S. (2015a). Neural bases of syntax–semantics interface processing. *Cognitive neurodynamics*, *9*, 317-329.
Malaia, E., & Newman, S. (2015b). Neural bases of event knowledge and syntax integration in comprehension of complex sentences. *Neurocase*, *21*, 753-766. doi: 10.1080/13554794.2014.989859
Malaia, E., Borneman, J. D., & Wilbur, R. B. (2017). Information transfer capacity of articulators in American Sign Language. *Language & Speech*. doi: 10.1177/0023830917708461 [First published online May 31, 2017]
McCullough, S., Saygin, A. P., Korpics, F., & Emmorey, K. (2012). Motion-sensitive cortex and motion semantics in American Sign Language. *Neuroimage, 63*, 111-118. doi: 10.1016/j.neuroimage.2012.06.029
Meir, I., Aronoff, M., Börstell, C., Hwang, S. O., Ilkbasaran, D., Kastner, I., Lepic, R., Lifshitz Ben-Basat, A., Padden, C., & Sandler, W. (2017). The effect of being human and the basis of grammatical word order: Insights from novel communication systems and young sign languages. *Cognition, 158*, 189-207. doi: 10.1016/j.cognition.2016.10.011
Napoli, D. J., & Wu, J. (2003). Morpheme structure constraints on two-handed signs in American Sign Language: Notions of symmetry. *Sign Language & Linguistics, 6*, 123-205. doi: 10.1075/sll.6.2.03nap
Newman, A. J., Supalla, T., Fernandez, N., Newport, E. L., & Bavelier, D. (2015). Neural systems supporting linguistic structure, linguistic experience, and symbolic communication in sign language and gesture. *Proceedings of the National Academy of Sciences, 112,* 11684-11689. doi:10.1073/pnas.1510527112
Oldfield, R. C. (1971). The assessment and analysis of handedness: the Edinburgh inventory. *Neuropsychologia, 9*, 97-113. doi: 10.1016/0028-3932(71)90067-4
Ortega, G., Özyürek, A., & Peeters, D. (2019). Iconic gestures serve as manual cognates in hearing second language learners of a sign language: An ERP study. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. Advance online publication. doi: 10.1037/xlm0000729
Osterhout, L., Holcomb, P. J., & Swinney, D. A. (1994). Brain potentials elicited by garden-path sentences: evidence of the application of verb information during parsing. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 20(4), 786.
Padden, C., Hwang, S. O., Lepic, R., & Seegers, S. (2015). Tools for language: Patterned iconicity in sign language nouns and verbs. *Topics in Cognitive Science, 7*, 81-94. doi: 10.1111/tops.12121
Philipp, M., Bornkessel-Schlesewsky, I., Bisang, W., & Schlesewsky, M. (2008). The role of animacy in the real time comprehension of Mandarin Chinese: Evidence from auditory event-related brain potentials. *Brain and Language, 105*(2), 112-133.
Picton, T. W. (1992). The P300 wave of the human event-related potential. *Journal of clinical neurophysiology*, *9*(4), 456-479.
Poizner, H., Klima, E. S., & Bellugi, U. (1987). *What the hands reveal about the brain.* Cambridge: The MIT Press.
Polich, J. (2007). Updating P300: An integrative theory of P3a and P3b. *Clinical Neurophysiology, 118*, 2128-2148. http://dx.doi.org/10.1016/j.clinph.2007.04.019
Polich, J. (2004). Neuropsychology of the P3a and P3b: A theoretical overview. In C. Moore & K. Arikan (Eds.), Brainwaves and mind: Recent developments (pp. 15–29). Wheaton, IL: Kjelberg.
Primus, B. (1999). *Cases and thematic roles*. Tübingen: Niemeyer.
Roehm, D., Bornkessel-Schlesewsky, I., Rösler, F., & Schlesewsky, M. (2007). To predict or not to predict: Influences of task and strategy on the processing of semantic relations. *Journal of Cognitive Neuroscience*, *19*(8), 1259-1274.
Sandler, W., & Lillo-Martin, D. (2006). *Sign language and linguistic universals*. Cambridge University Press.

Schalber, K. (2006). What is the chin doing? An analysis of interrogatives in Austrian Sign Language. *Sign Language & Linguistics*, 9, 133-150. doi: 10.1075/sll.9.1-2.08sch

Schalber, K. & Hunger, B. (2001) BUB FUSSBALLSPIELEN KÖNNEN - Untersuchungen zur Stellung von Modalverben in der Steirischen Variante der Österreichischen Gebärdensprache. *Grazer Linguistische Studien*, 56, 37-46.

Schalber, K. & Hunger, B. (2008). Possession in Austrian Sign Language (ÖGS) - with existentials on the side. In: P. M. Perniss & U. Zeshan (Eds.), Possessive and existential constructions in sign languages. (Sign language Typology Series No. 2) (pp. 151-180). Nijmegen: Ishara Press.

Shepard-Kegl, J. (1985). *Locative relations in American Sign Language word formation, syntax and discourse* (Doctoral dissertation, Massachusetts Institute of Technology). Retrieved from https://scholar.google.at.

Skant, A., Dotter, F., Bergmeister, E., Hilzensauer, M., Hobel, M., Krammer, K., Okorn, I., Orasche, C., Orter, R., & Unterberger, N. (2002). *Grammatik der Österreichischen Gebärdensprache.* Klagenfurt: Veröffentlichungen des Forschungszentrums für Gebärdensprache und Hörgeschädigtenkommunikation der Universität Klagenfurt (Vol. 4).

Strickland, B., Geraci, C., Chemla, E., Schlenker, P., Kelepir, M., & Pfau, R. (2015). Event representations constrain the structure of language: Sign language as a window into universally accessible linguistic biases. *Proceedings of the National Academy of Sciences*, *112*, 5968-5973. doi: 10.1073/pnas.1423080112

Van Petten, C. & Kutas, M. (1990). Interactions between sentence context and word frequency in event-related brain potentials. *Memory and Cognition, 18*(4), 380–393.

Van Petten, C., & Luka, B. J. (2012). Prediction during language comprehension: Benefits, costs, and ERP components. *International Journal of Psychophysiology*, *83*(2), 176-190.

Volterra, V., Laudanna, A., Corazza, S., Radutzky, E., & Natale, F. (1984). Italian Sign Language: The order of elements in the declarative sentence. In F. Loncke, P. Boyes-Braem & Y. Lebrun (Eds.), *Recent research on European Sign Languages* (pp. 19-48). Lisse: Swets and Zeitlinger.

Wang, L., Schlesewsky, M., Bickel, B., & Bornkessel-Schlesewsky, I. (2009). Exploring the nature of the 'subject'-preference: Evidence from the online comprehension of simple sentences in Mandarin Chinese. *Language and Cognitive Processes, 24*(7-8), 1180-1226. doi: 10.1080/01690960802159937

Wilbur, R. B. (2002). Phrase structure in ASL and ÖGS. In R. Schulmeister & H. Reinitzer (Eds.), *Progress in sign language research. In honor of Siegmund Prillwitz* (pp. 235-247). Hamburg: Signum.

Wilbur, R. B. (2005). Evidence from ASL and ÖGS for asymmetries in UG. In A. M. DiScuillo (Ed.), *UG and external systems: Language, brain and computation* (pp. 193-210). Amsterdam: John Benjamins.

Wilbur, R. B., Bernstein, M. E., & Kantor, R. (1985). The semantic domain of classifiers in American Sign Language. *Sign Language Studies, 46*, 1-38. doi:10.1353/sls.1985.0009

Tables & Figures

Figure 1. Example representing the two experimental conditions: Both arguments were referenced in space by a classifier handshape (in this case the two referents are placed in space in a way indicating that they are standing opposite each other with more distance between them). Then, either the hand representing the first referent (signer's left hand in SOV orders) or the second referent (signer's right hand in OSV orders) started to move; i.e. indicating the active referent. The sentence shown means: "Two girls stand opposite each other and one of them (either the one on the left or the one on the right side) jumps towards the other." Signs are glossed with capital letters

Figure 2. Top: Comparison of SOV vs. OSV conditions with regard to the time point when the classifier predicate started its movement. The vertical line represents the time point at which the first frame when the hand referencing the subject starts to move was visible. Negativity is plotted upwards. The red square marks the time window in which the effect of ORDER became significant (300–800 ms time window). Bottom: The topographic plots illustrate the corresponding voltage difference between the two conditions over the epoch of interest, i.e. from 300 and 800 ms showing the broad scalp distribution of the N400 effect.

Classifier processing strategy:	**SOV word order**	**OSV word order**
Linguistically-goverened processing	baseline	enhanced N400 compared to SOV
Gestural-semiotic processing	baseline	no enhanced N400 compared to SOV

Table 1. Processing hypotheses and their predictions.

	SOV	OSV
Trigger 1	86 %	85 %
Trigger 2	87 %	86 %

Table 2. Remaining trials after artifact rejection (per condition at time/first frame at which the hand referencing the subject started to move).

Condition	**Mean acceptability (*sd*)**	**Mean reaction time in ms (*sd*)**
SOV	5.76 (0.92)	870.18 (446.90)
OSV	5.67 (0.90)	896.84 (460.53)

Table 3. Mean ratings and mean reaction times for the two experimental conditions. Standard deviation (*sd*) is presented in parentheses.