Diane Brentari*, Laura Horton and Susan Goldin-Meadow

Crosslinguistic similarity and variation in the simultaneous morphology of sign languages

https://doi.org/10.1515/tlr-2020-2055

Abstract: Two differences between signed and spoken languages that have been widely discussed in the literature are: the degree to which morphology is expressed simultaneously (rather than sequentially), and the degree to which iconicity is used, particularly in predicates of motion and location, often referred to as classifier predicates. In this paper we analyze a set of properties marking agency and number in four sign languages for their crosslinguistic similarities and differences regarding simultaneity and iconicity. Data from American Sign Language (ASL), Italian Sign Language (LIS), British Sign Language (BSL), and Hong Kong Sign Language (HKSL) are analyzed. We find that iconic, cognitive, phonological, and morphological factors contribute to the distribution of these properties. We conduct two analyses—one of verbs and one of verb phrases. The analysis of classifier *verbs* shows that, as expected, all four languages exhibit many common formal and iconic properties in the expression of agency and number. The analysis of classifier *verb phrases* (VPs)—particularly, multiple-verb predicates—reveals (a) that it is grammatical in all four languages to express agency and number within a single verb, but also (b) that there is crosslinguistic variation in expressing agency and number across the four languages. We argue that this variation is motivated by how each language prioritizes, or ranks, several constraints. The rankings can be captured in Optimality Theory. Some constraints in this account, such as a

This work was supported in part by NSF grant BCS-1227908 to Brentari, and BCS-1918545 to Brentari and Goldin-Meadow. We would like to acknowledge our deaf and hearing collaborators for their crucial help on this project: Jordan Fenlon for collecting the BSL data, Chiara Branchini and Gabriele Caia for collecting the LIS data, and Gladys Tang and her team for collecting the HKSL data.

***Corresponding author: Diane Brentari**, Department of Linguistics, University of Chicago, Chicago, USA, E-mail: dbrentari@uchicago.edu
Laura Horton, Department of Linguistics, University of Texas - Austin, Austin, USA, E-mail: laurahorton@utexas.edu
Susan Goldin-Meadow, Departments of Psychology and Comparative Human Development, University of Chicago, Chicago, USA, E-mail: sgm@uchicago.edu

constraint to be redundant, are found in all information systems and might be considered non-linguistic; however, the variation in constraint ranking in verb phrases reveals the grammatical and arbitrary nature of linguistic systems.

Keywords: crosslinguistic variation; morphology; multiple-verb predicates; Optimality Theory; sign languages

1 Introduction

Early studies of morphological structure in American Sign Language (ASL) described it as a *predicate classifier* language (Allan 1977) because classifier morphemes affix to verbs. Classifier predicates are attested in most documented sign languages (Engberg-Pedersen 1993; Kyle and Woll 1983; Mathur and Rathmann 2010; Pizzuto 1987; Supalla 1982; Wallin 1994), and their simultaneous morphological complexity has often been attributed to the visual-manual modality in which sign languages are produced (Aronoff et al. 2005; Emmorey 2002; Meir 2002; Perniss et al. 2015). Research on ASL classifier predicates (Klima and Bellugi 1979; Padden 1988; Schick 1990; Supalla 1982) emphasized that, in contrast to the sequential linear realization of multi-morphemic predicates in spoken languages, morphemes in sign languages could be realized simultaneously within a single verb (see Figure 1 for an example).

In this paper, we present evidence that, despite the potential for simultaneity afforded by the visual modality, there are limits on the nature and quantity of information packaged in the simultaneous morphology of sign language classifier

Figure 1: ASL classifier predicate, from Brentari (1998, 2019). [movement = GO-TO] [bent finger = HUNCHED-OVER] [index finger = PERSON] [nonmanual "mm" = CAREFULLY]. Each element in brackets is a morpheme, and all four morphemes are produced simultaneously.[1]

1 The parts of the form that convey the meanings "forward" (movement direction), "two" (using the two hands) and "side-by-side" (two hands held next to each other) may not be productive or systematic enough to be morphemic, according to criteria in Matthews (1991).

predicates. We thus echo a finding from Supalla (1990), who found cases where manner and path were sequentially expressed in ASL classifier verbs, even if they occurred simultaneously as a single event—e.g., *the rabbit* ***hopped (manner)*** + ***in a circle (path)***. Supalla argued that there are linguistic limitations on simultaneous morphology in ASL: "Even when the aspects of an event are simultaneous, there are circumstances in which the corresponding ASL morphemes must be distributed over a series of separate verbs of motion" (Supalla 1990, p. 127).

To further explore the circumstances where morphology occurs sequentially rather than simultaneously in sign languages, we analyze structures involving agency of the subject (no-agent, agent) and the number of events (singular, plural) from four sign languages—American Sign Language (ASL), British Sign Language (BSL), Hong Kong Sign Language (HKSL), and Italian Sign Language (LIS). In Figure 2, we illustrate the three properties of classifier predicates that we investigate in this paper: handshape type, movement axis, and movement repetition. The first property is *handshape type*. In Figure 2a and b the signer uses an index-finger-handshape to iconically represent the shape of an object that is long and thin, an *object handshape*; in Figure 2c and d, she uses a flat-O-handshape to iconically represent a hand that is holding a small, long, thin object, a *handling handshape*. The second property is *movement axis*. In Figure 2a and b the signer produces a vertical movement in neutral space without reference to the body, called the *lateral axis*, to indicate the location of the event; in Figure 2c and d, the signer produces a movement anchored at the body and moving away from the signer's body, called the *midsagittal axis*. The third property is *movement repetition*. In Figure 2a and c the signer produces one movement with a single trajectory to represent a single event; in Figure 2b and

Figure 2: The handshape and movement features analyzed in this paper include: handshape type, movement axis, and movement repetition: (a) an object handshape combined with single and (b) plural (repeated) lateral movement; (c) a handling handshape combined with single and (d) plural (repeated) midsagittal movement. The handshapes express "long, thin object" (a, b) and "handle long, thin object" (c, d).

d, she produces repetitions of the movement trajectory to represent multiple events.[2]

In this paper we ask how handshape type, movement axis, and repetition are combined in descriptions of events that include a human actor and multiple actions or objects, where we might anticipate that agency and plurality would both be expressed. Agency and plurality are two types of morphology that are expressed in similar (though not identical) ways across sign languages; some of these similarities appear to be based on the affordances of iconicity (see Section 2). We suggest that the preferences we find within and across several sign languages are due to multiple competing pressures: iconic, phonological (articulatory, perceptual), morphological (compositional vs. fusional), and cognitive (processing time). We suggest that the productive, recombinable nature of simultaneous sign language morphology may come with processing costs. The sequentialization strategies suggested by Supalla (1990) for path and manner, and the strategies for agency and plural morphology that we describe here, are grammatical ways of dealing with the tension between temporal efficiency and redundancy. We describe single-verb and multiple-verb[3] VPs in ASL, BSL, HKSL, and LIS, and find evidence for both crosslinguistic similarities and variation in how languages respond to these competing pressures.

2 Background

We acknowledge both the iconic and grammatical nature of classifier constructions, and one of the main goals of this paper to address how the iconicity seen in single verbs can be reorganized in a grammatical fashion at the level of the verb phrase. In the sections that follow, we review the relevant literature addressing the interaction between iconicity and grammar in classifier constructions.

2.1 Expressing agents in classifier constructions: handshape and movement axis

The analysis of sign language classifier constructions has been extensively debated (Schick 1990; Supalla 1982; see also Emmorey 2003 and Zwitserlood

2 The *vertical* axis is also a part of the lateral axis forms. This property of movement has been argued to be associated with a definite location (Supalla 1982; Wallin 1994). It does not bear on the analysis here, and will not be discussed further.

3 Lacking the necessary diagnostics to identify serial verbs (see Lau 2012, for such diagnostics in Hong Kong Sign Language), we do not refer to these multiple-verb constructions as "serial verbs".

2012, for excellent overviews). However, most researchers agree that a classifier construction in a sign language consists of a verbal root–the movement of the sign–and a handshape affixal morpheme (Supalla 1982), similar to spoken languages with verbal classifiers, exemplified in Waris, a language of Papua New Guinea (1).

(1) Waris classifier predicates (Brown 1981, p. 95ff)

a. sa ka-m **put-** ra-ho-o
coconut I-dat **class[round]** get-benefactive-imperative
"Give me a coconut."

b. nelus ka-m **ninge-** ra-ho-o
greens I-dat **class[leaf-wrapped]** get-benefactive-imperative
"Give me greens (cooked in their leaf wrapper)."

There is also general agreement that classifier constructions constitute some of the most iconic forms of a sign language lexicon (Brentari and Padden 2001; Padden 1998), and while iconic meaning is not the same as morphology, this iconicity often interacts with grammatical patterns. A morpheme is a structural unit that creates a discrete, productive opposition in form and meaning. Formal diagnostic tests are needed for this determination to be conclusive, such as scope of negation and tests for agency. Such tests have been used to establish handshape's morphological status. Object handshapes, such as those in Figure 2a and b, are associated with intransitive non-agentive predicates, and handling handshapes, such as those in Figure 2c and d, are associated with transitive, agentive predicates (Benedicto and Brentari 2004; Mazzoni 2008; Zwitserlood 2003).[4] Moreover, when gesturers and signers performed this task in related studies (Brentari et al. 2012, 2015a, b, 2016; Goldin-Meadow et al. 2015), they did not show the same systematic use of handshape. Several studies comparing silent gesture and sign language in children and in adults show different patterns of use in gesture versus sign in classifier constructions (or classifier-like gestures) such as the ones we analyze here; therefore, while one might think that it would be intuitive for signers and gesturers alike to use iconic handshape and movement properties with a clear and productive distribution, such as we report here for signers, we find time and again that gesturers not do this (Brentari et al. 2012, 2016; Goldin-Meadow et al. 2015; Goldin-Meadow and Brentari 2017 and references therein). The current study builds on that previous work showing that object and handling handshapes are used linguistically in sign languages, but not in gesture.

The axis of movement in classifier constructions can also express agentive values in ASL (Horton et al. 2015). Movements produced with a lateral axis are

4 See Kimmelman et al. (2020) for an alternative analysis of handling handshapes in classifier predicates in Russian Sign Language (RSL).

associated with non-agentive predicates (Figure 2a and b); movements with a midsagittal axis are associated with agentive predicates (Figure 2c and d). The midsagittal axis is anchored by the body, either at the beginning or end of the movement, iconically drawing the signer's body into the structure (Horton et al. 2015). Diagnostic tests for morphological structure comparable to the tests Benedicto and Brentari (2004) performed for handshape have not yet been carried out for movement, thus we cannot at this time conclusively extend morphological status to movement axis. However, both handshape and movement axis are systematically and productively used in classifier constructions to express the presence of an agent in an event, and systematicity and productivity are two important characteristics of morphology. In this paper, we analyze the distribution of these properties and ask what happens when properties associated with agency (handshape type, movement axis) are combined with those associated with plurality (repetition).

2.2 Repetition expressing plural marking in sign languages

In addition to handshape type and movement axis, in the current analysis we also consider another iconic property of movement, namely repetition.[5] Prior cross-linguistic work on number marking in sign languages has shown that movement repetition is associated with plurals. Multiple iterations of movement iconically map onto multiple events (Coppola et al. 2013; Fischer 1973; Fischer and Gough 1978; Pfau and Steinbach 2005, 2006), both in classifier constructions (which express spatial events) and in "core" vocabulary (nouns and verbs that express non-spatial events; see Brentari and Padden 2001). In core verbs, plurals can be combined with spatio-temporal aspectual meanings, e.g., [verb] + TO EACH (Klima and Bellugi 1979; Wilbur et al. 1983). In core nouns, plurals can be expressed in a number of ways, and these patterns can be extended to static events expressed as classifier constructions. In an inventory of pluralization strategies in German Sign Language (DGS), Pfau and Steinbach (2005, 2006) identify zero marking (no marking), simple reduplication (each repetition is in the same place as the previous one), and sideward reduplication (each repetition is next to the previous one in a new location moving sideways from the signer) as formal strategies for marking plurality. Zwitserlood (2012) and Zwitserlood and Nijhoff (1999) make similar

5 We will describe the movement patterns in this paper as "repetition" rather than "reduplication," because the term is more theory-neutral and process-neutral. See Kimmelman (2018) for a discussion of repetition versus reduplication in Russian Sign Language and Wilbur (2009) for a discussion of productive reduplication in ASL.

observations about the reduplication of movement in classifier constructions in Sign Language of the Netherlands (NGT), as do Perniss et al. (2015) for Turkish Sign Language (TiD). In our analysis, we analyze the distribution of repetition in the four target sign languages in order to determine their crosslinguistic similarities and differences, particularly when plurality is combined with agency.

Agency and plurality are typically analyzed separately, thus we contribute to previous work by considering agency and plurality together in the same analysis: agency expressed in two ways—via handshape type and via movement axis—and plurality expressed via repetition. We also analyze productions across several contrasting contexts—agentive and non-agentive productions, singular and plural forms. In addition, we analyze predicates expressed as a single-verb VP (svVP, e.g., *I [[go-towards-him]$_V$]$_{VP}$*), as a multiple-verb VP (mvVP, e. g., *I [[tiptoe]$_V$ + [go-towards-him]$_V$]$_{VP}$*), or as a multiple VP (VP+, e. g., *I [[go-towards-him]$_V$]$_{VP}$ + I [[go-towards-him]$_V$]$_{VP}$ + I [[go-towards-him]$_V$]$_{VP}$*). These categories will be described in more detail in the next section. We will argue that the languages targeted in this study have strong similarities at the level of the verb, and that crosslinguistic variation occurs primarily at the level of the verb phrase, particularly in the degree to which the languages employ redundancy as a grammatical strategy.

2.3 The role of redundancy as a constraint in grammatical constraints

Redundancy in information theory has a vast literature (see Reza 1991 and references therein) and is observed in many human domains, not only language (Colby 1958). However, the degree to which a language string includes as much new information as possible (i.e., less redundancy) or as much old information as possible (i.e., more redundancy) is a key to effective communication (Ashby 1965; Hsia 1977). More redundant information makes the receiver's task easier because the same meaning is produced in more than one form. In sign languages, one example of this is when a clause has both a negative headshake and a negative sign to express negation (2a). Receivers can understand the meaning if they notice either the headshake or the negative sign. Less redundancy makes the receiver's task more difficult. If a negative headshake does not occur with a negative sign, as in (2b), the receiver has only one chance to notice the negative meaning.

(2a) _____neg
GIRL **NOT** WRITE LETTER

(2b) _____neg
GIRL Ø WRITE LETTER

Sign languages are claimed to have more simultaneous information than spoken languages, and the meanings that are simultaneously layered are produced by different articulators, as in Figure 1. Handshape type and movement axis both mark agency; thus these two parameters of articulation have the potential to be *redundant*. We therefore ask: To what extent is redundancy important in expressing agency? Do the four languages prefer to have handshape and movement axis convey the same agentive meaning, maximizing redundancy? We also ask about simultaneity with respect to agency and plurality: Do the languages prefer agency and plurality to be expressed simultaneously in one verb, as one might expect from the previous sign language literature?

2.4 Using Optimality Theory to capture variation

Optimality Theory (OT) uses different rankings of the same set of grammatical constraints across languages to show crosslinguistic variation (Prince and Smolensky 1993). In initial proposals within an OT framework, the aim was to find the single "winning candidate" from among a set of possible candidates based on a set of ranked constraints. In later proposals, often referred to as *probablistic OT*, a less categorical, more gradient, approach to grammaticality was employed, which aimed to not only capture a single winning candidate, but to allow a broader range of candidates within a grammar to be grammatical on the basis of quantitative learning algorithms (e.g., Boersma and Hayes 2001; Goldwater and Johnson 2003; Hamanna et al. 2012). Typically, probablistic OT operates on large corpora using sophisticated modelling techniques to arrive at a more gradient concept of acceptability or grammaticality. The crosslinguistic analysis of verb phrases employed here is in the spirit of probablistic OT, because more than one form is considered grammatical. Our analysis is more modest than most applications of probablistic OT, however, because our data set is relatively small compared to those used in spoken languages, and instead of powerful algorithms, we will use the number of violations of each constraint in each language as the means to rank constraints.

To summarize, we ask how agency and plurality are expressed in individual classifier verbs and in verb phrases with multiple classifier verbs. Do the four target languages use both handshape type and movement axis to mark agency redundantly within a single verb? Or do the languages use handshape type to mark agency and reserve movement features for marking plurality? Are agency and plurality expressed within a single verb, or are they spread across more than one verb? And finally, do the four languages make the same decisions with respect to these properties in classifier constructions?

3 The present study

3.1 Languages and participants

The 16 participants in this study are all Deaf, native signers, defined as having Deaf signing parents, and are from four different linguistic communities. The four American Sign Language (ASL) signers (all female) are from the greater Chicago area (mean age 45.5, range 33–62). The four British Sign Language (BSL) signers (two males, two females) are from London (mean age 47.2, range 32–60). The four Italian Sign Language (LIS) signers (two males, two females) are from the Veneto region of Italy (mean age 32.5, range 30–39), and the four Hong Kong Sign Language (HKSL) signers (two males, two females) are from Hong Kong (mean age 32.2, range 29–37).

These four sign languages were chosen for this study because they are largely historically unrelated to one another. BSL is a member of a sign language family known as BANZSL (British, Australian, New Zealand Sign Language, Johnston and Schembri 2007). HKSL is part of a sign language family that includes Chinese Sign Language, specifically the Nanjing/Shanghai dialects (Sze et al. 2013; Woodward 1993). ASL and LIS are historically related to Old French Sign Language due to the diffusion of pedagogical methods of sign language in the late eighteenth century, but both were heavily influenced by indigenous varieties of their respective languages and have been separate languages for at least 250 years (Lane 1984; Pinna et al. 1993).

3.2 Materials

The stimulus materials for this study are a series of still photographs and short video clips called "vignettes." This set of vignettes has been used with signers of multiple sign languages. In addition to the sign languages sampled for this study, the vignettes have been used in studies of Turkish Sign Language (TiD; Hakgüder and Brentari 2018), Nicaraguan Sign Language (NSL; Goldin-Meadow et al. 2015), and Central Taurus Sign Language (CTSL; Ergin and Brentari 2017). The vignettes include a set of 11 hand-held objects: toy planes, books, pens, lollipops, tweezers, televisions, cigars, marbles, coins, strings, and pieces of tape. Participants describe each object in 11 different conditions. Half of the vignettes include a human actor, indicated by the presence of a hand placing an object or objects on a table; the remaining vignettes do not have any representation of a human agent. The *agent* conditions, with a hand placing objects on a table, includes two events with one object (*agent single* conditions) and two events with four to seven objects (*agent multiple* conditions). Participants also describe four *no-agent* conditions, two in which one object is

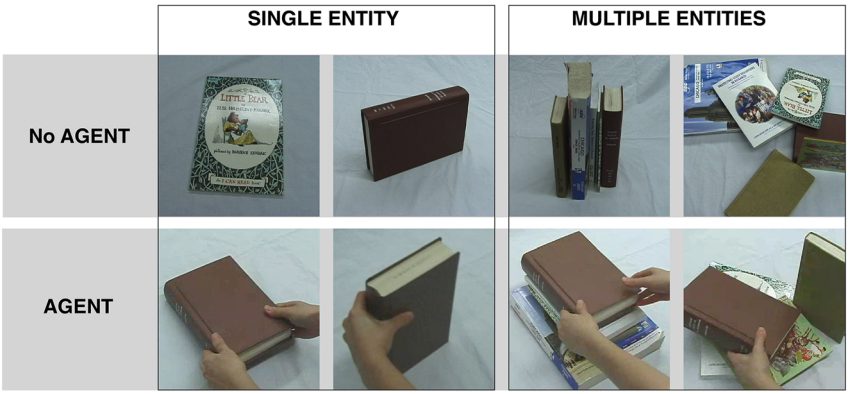

Figure 3: Sample images from stimuli vignettes. Top row: no-agent, single (left), and no-agent, plural (right). Bottom row: agent, single (left) and agent, plural (right).

located on a table (*no-agent single* conditions) and two in which four to seven objects are located on a table (*no-agent multiple* conditions).[6] There is one additional condition in which the object falls off the edge of a table, and two conditions in which a person engages in an action with the object, either a typical activity (e.g., reading a book) or an atypical activity (e.g., fanning yourself with a book).

For this study, we analyze descriptions of 32 vignettes—four objects (toy airplanes, books, pens, and lollipops) x eight conditions: two vignettes with a hand placing a single object [agent single], two with a hand placing multiple objects [agent plural], two with a single object located on a table [no-agent single], and two with multiple objects located on a table [no-agent plural]). Each of the four objects thus appears in a paradigm of events with or without an agent, and with single or multiple objects (see Figure 3 for examples).

3.3 Procedure

Participants watched the vignettes on a laptop computer, and were asked to describe what they saw to a fluent signer of the target sign language while being filmed.[7] The filmed descriptions were saved as files and clipped by item to be further annotated using ELAN (Crasborn and Sloetjes 2008).

6 In the two versions of each condition, the item is presented in a "canonical" or expected position or arrangement (a row of items, a pen laying on the table) and then in a "strange" or unusual position or arrangement (a messy pile of pens, an upside down lollipop).

7 The interlocutor was a hearing, early learner of ASL in one case, and a native signer in all other cases.

3.4 Annotation

The participants described the stimuli vignettes using sentences of varying lengths. Some descriptions were very brief while others included details about the individual objects and their spatial arrangement and orientation. In general, signers first provided a lexical item (i.e., a noun) for the object in the vignette (typically the lexical sign for airplane, pen,[8] lollipop, or book) followed by one or more verbs or verb phrases. Each description was considered a single *utterance*.

There were two annotators who independently annotated the data along each dimension we are about to describe; at least 20% of annotations along each dimension were annotated by both annotators to obtain reliability. We annotated each sign for *sign type*–whether it was a noun that labeled the object in the vignette, a classifier predicate that described what happened in the vignette, or other signs conveying additional information about the objects, such as their color or size. We also identified the target predicate description; specifically, which classifier verb (or verbs) referred to the events in the vignette. Intercoder agreement for determining the target description, and whether a sign was a lexical item, classifier verb, or other signs conveying additional information was 100%. Each target verbal description was then coded for four properties: handshape type, movement axis, movement repetition, and constituent type.

The handshape types that we coded were: *object handshapes, handling handshapes,* or *other handshapes*. As described earlier, object handshapes capture the shape of the object itself and include whole-entity handshapes and size and shape specifiers (SASSs). Handling handshapes capture the shape of the agent's hand on the object. Other handshapes trace the outline of an entity or are ambiguous (Other handshapes comprised less than 5% of the data). Inter-coder agreement for coding handshape type was 94%.

The movement axes that were coded were: *midsagittal, lateral,* or *ambiguous*. The movement path began when the handshape for the verb was fully formed and tense and ended when the handshape changed or relaxed. Verbs with a midsagittal axis ("body-anchored") started or ended in close proximity to the body; the primary trajectory of the movement was toward or away from the body. Verbs with a lateral axis were not body-anchored, had a primary trajectory that was vertical or horizontal, and were produced in the signing space in front of the signer's torso. If the movement axis of a sign could not be determined, it was coded as ambiguous (4% of the relevant data). Intercoder agreement for coding movement axis was 91%.

---

8 ASL signers frequently fingerspelled the word P–E–N rather than produce the lexical sign.

Repetition was annotated as *no repetition* ([–rep]; single movement), *repetition within a single verb phrase* ([+rep]; no signs between repetitions),[9] or *repetition across verb phrases* ([+VP, –rep]). Repetition across verb phrases consisted of a sequence of single-movement verbs. The VPs contained multiple instances of the same verb without any movement repetition [–rep]. Each instance of the verb was preceded or followed by a modifier. Intercoder agreement for coding repetition was 98%.

Finally, we annotated the nature of the constituent type used in the description. We considered each description to be a single utterance.[10] An utterance could consist of a *single verb*, which could be ±repetition, in a verb phrase (svVP; e.g., PUT $[\pm rep]_V]_{VP}$); *multiple verbs*, which could be ±repetition, in a verb phrase (mvVP; PUT $[\pm rep]_V$ + BE-LOC$[\pm rep]_V]_{VP}$); or *multiple verb phrases* (VP+), which are multiple instances of the same verb without repetition, each with an intervening modifier between the verbs, such as a color term or indication of size or shape (e.g., [BLUE + [PUT $[-rep]]_V]_{VP}$, [TALL + [PUT$[-rep]]_V]_{VP}$, [WIDE + [PUT$[-rep]]_V]_{VP}$). Each verb + modifier structure was annotated as a VP. Inter-coder agreement for constituent was 95%.

4 Results

We begin with an analysis of the frequency of each of the features that were annotated in relation to the type of vignette described. We first describe the distribution of features within single verbs, then consider how they are combined within VPs and utterances.

Signers often produced one or more verbs in their descriptions of stimuli vignettes. The results in Sections 4.1–4.3 include analyses of 905 *verbs* (266 ASL, 201 BSL, 193 HKSL, and 245 LIS), which address the simultaneous combinations of

Figure 4: Typical ASL mvVP response to an agent, multiple vignette.

9 A verb with repetition form could either be what Coppola et al. (2013) call "unpunctuated", a single fluid movement, or "punctuated", a repetition with short pauses between the repetitions.
10 Given an elicited set of descriptions such as this one, without language-specific diagnostics for mono-clausality, we employed the utterance rather than a syntactic unit for purposes of labeling the entire description (for an excellent discussion of criteria for mono-clausality, see Loos 2017).

the handshape, axis, and repetition in a single verb. The results in Section 4.4 are based on analyses of 501 *utterances* (122 ASL, 124 BSL, 127 HKSL, and 128 LIS), which address the types of constituents (svVP, mvVP, or VP+) used in the vignette descriptions. We provide a typical mvVP response to an agent, multiple vignette from the ASL data in Figure 4.

4.1 Analysis of verbs

We begin by presenting the frequency and distribution of the three features introduced above in all 905 verbs in the data set: handshape type, movement axis, and movement repetition. We replicated prior findings from ASL regarding the association between handshape type and movement axis as markers of agency using the same dataset as Horton et al. (2015), Brentari et al. (2013, 2015a, 2015b) and Goldin-Meadow et al (2015), as well as movement repetition as a marker of number (Fischer 1973; Fischer and Gough 1978). Data from the three new sign languages (LIS, HKSL, BSL) demonstrate that handshape and movement axis are robust crosslinguistic strategies for marking agency and, similarly, that movement repetition is a robust crosslinguistic strategy for number marking.

4.1.1 Handshape type

As described in the introduction, two of the most common iconic handshape types in classifier verbs of movement and location are *object handshapes*, which iconically represent the shape of an object and *handling handshapes*, which iconically resemble how an object is manipulated by a hand. All signers produced both handshape types in descriptions of the four items in the vignettes, albeit at different rates. Overall, verbs with an object handshape were produced more frequently (0.58–0.65 across all languages) than verbs with a handling handshape (0.33–0.42); see Table 1.

In previous studies of these data (Brentari et al. 2012, 2013, 2015a, b; Goldin-Meadow et al. 2015), handling and object handshape types were analyzed as markers of the presence or absence of a human agent in an event. The handshape

Table 1: Frequency of handling handshapes and object handshapes.

Language	Object HS	Handling HS	Total
ASL	174 (0.65)	88 (0.33)	266
BSL	121 (0.60)	80 (0.40)	201
HKSL	110 (0.57)	80 (0.41)	193
LIS	142 (0.58)	103 (0.42)	245

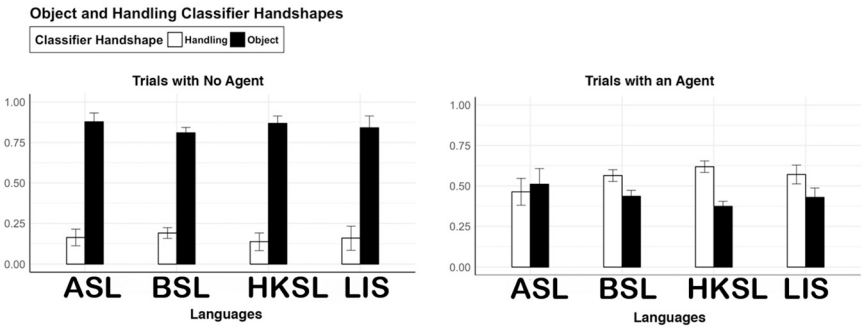

Figure 5: Average proportion of handshape type in descriptions of events that vary in agency, in trials with no agent (left) or in trials with an agent (right). Predicates were produced with either a *handling* handshape (white bars) or *object* handshape (black bars). *Other* handshapes (<5% of the total) have been excluded. Error bars indicate standard error.

analysis for ASL was replicated, and for BSL, HKSL, and LIS the analysis was done for the first time. The results are presented in Figure 5 and show the strong association between object handshapes and trials with no agent (0.81–0.88, Figure 5, left), and the weaker association between handling handshapes and trials with an agent (0.46–0.62, Figure 5, right).[11]

Verbs with handling and object handshapes are produced with equal frequency in descriptions of agentive events, but verbs with handling handshapes are rarely produced in descriptions of non-agentive events. A handling handshape is thus a reliable indicator that the described vignette includes a human agent, but predicates with an object handshape are produced in descriptions of either type of event. One explanation for the large proportion of verbs with an object handshape in descriptions of events with an agent could be that object handshapes *lack* a specification for agency and thus might be produced along with another sign containing a marker for agency in a multiple verb VP (mvVP). We explore this possibility in Section 4.4.

4.1.2 Movement axis

The distribution of movement axis is comparable to the distribution found for handshape type. Signers produce movements with both axis types, but the movements were not produced at equal rates. Overall, verbs with a lateral

11 Predicates that received a code of *other* for handshape type or *ambiguous* for movement axis are included in the total, but are not presented as proportions. For each language, *other* handshapes and *ambiguous* movements constituted less than 5% of the data.

Table 2: Production of predicates with a lateral movement axis or a midsagittal movement axis as a proportion of total target verbs.

Language	Lateral axis	Midsagittal axis	Total
ASL	198 (0.74)	64 (0.24)	266
BSL	140 (0.70)	60 (0.30)	201
HKSL	127 (0.66)	63 (0.33)	193
LIS	158 (0.64)	80 (0.32)	245

The ASL data were previously analyzed, and we confirm the results reported in Brentari et al. (2015a, b) and Goldin-Meadow et al. (2015).

movement axis (0.64–0.74) were more common than verbs with a midsagittal axis (0.24–0.33) across all four languages (Table 2). Predicates with a midsagittal axis have been shown to be more frequently produced in descriptions of agentive events in ASL (Horton et al. 2015); this finding was replicated for ASL and extended to BSL, HKSL, and LIS (Figure 6). Midsagittal axis is therefore an additional reliable marker of agency, along with handling handshape.

Predicates with a lateral axis are produced in descriptions of both agentive events and events with no human agent. As with handshape, one explanation for this distribution might be that lateral axis *lacks* an agentive status (i.e., it is not marked for agency) and thus might be produced along with another sign containing a marker for agency in a mvVP. Midsagittal movements might be less frequent on phonetic grounds as well, since they are articulatorily more complex. A midsagittal movement requires engaging at least two joints from among the wrist elbow, and shoulder, whereas a lateral movement requires only one (elbow). We

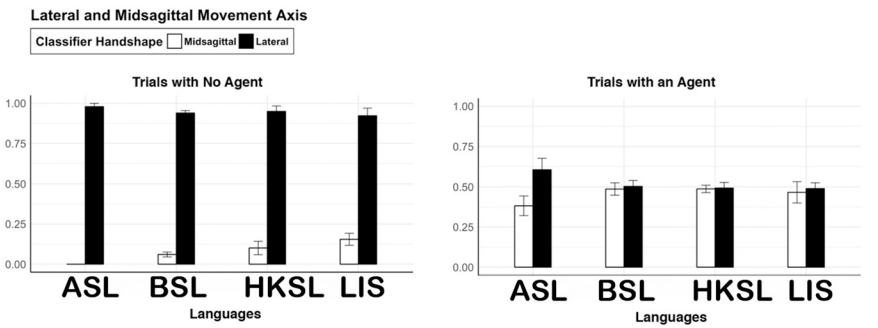

Figure 6: Average proportion of verbs with a midsagittal movement axis (white bars) and lateral movement axis (black bars) in descriptions of events with no agent (left graph) and descriptions of events with an agent (right graph). Movement axes coded ambiguous (<5% of the total) have been excluded. Error bars indicate standard error.

analyze this pattern further in Section 4.4. We turn next to the second movement feature in this analysis, movement repetition.

4.1.3 Movement repetition

Stimulus vignettes contained scenes with either a single action or multiple actions. We ask how participants mark this distinction in the verbs they produced. We first present the frequency of verbs with and without movement repetition across all descriptions of vignettes (see Table 3).

Table 3: Frequency of verbs with and without movement repetition.

Language	Movement without repetition	Movement with repetition	Total
ASL	198 (0.74)	68 (0.26)	266
BSL	113 (0.57)	87 (0.44)	201
HKSL	107 (0.55)	86 (0.45)	193
LIS	150 (0.61)	95 (0.39)	245

Movements without repetition (a single path) are more common (0.55–0.74) than movements with repetition (0.26–0.45) across all sign languages, but particularly for ASL. Movement repetition was common in descriptions of vignettes with multiple objects, and entirely absent in descriptions of vignettes with a single object (see Figure 7).

Predicates with movement repetition are produced only to describe events with multiple objects, making movement repetition a reliable marker of plurality. In contrast, predicates without movement repetition are produced to describe both events with one object and events with multiple objects, suggesting that the

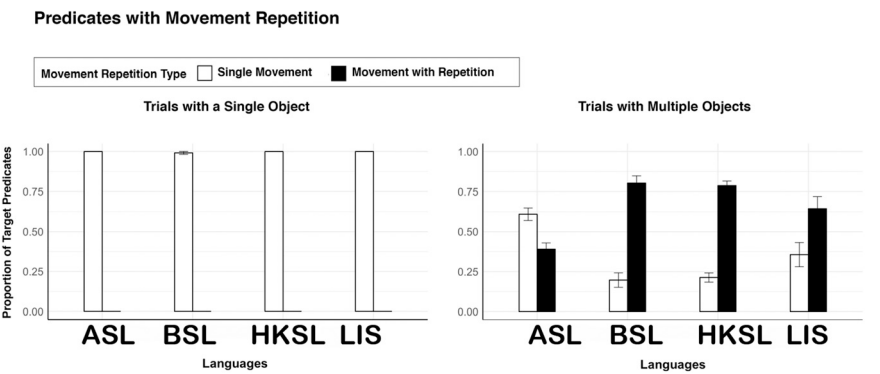

Figure 7: Average proportion of verbs with (black bars) and without (white bars) movement repetition in descriptions of vignettes with a single event (left) or multiple events (right).

absence of repetition does not necessarily suggest a singular event or object. Thus, similar to what we have seen for object handshape and lateral movement, [–rep] verbs may simply *lack* a number specification and be free to combine with other morphemes in the verb. We provide an analysis of crosslinguistic differences in plural marking in Section 4.4.

4.2 Combinations of handshape type and movement axis in verbs

In this analysis, we consider how handshape and movement features are combined in verbs. We ask whether all combinations are attested, and whether some combinations of handshape and movement axis are more frequent than others. We analyze the frequency of each combination as a function of the agency of the described event. We introduce the notion of REDUNDANCY, which is a tendency to

Table 4: Average frequency and proportion of handshape and movement axis combinations. Illustrations of each combination are provided in Figure 8.

Language	Redundant (8a) Object-HS and lateral axis	Non-redundant (8b) Object-HS and midsagittal axis	Non-redundant (8c) Handling-HS and lateral axis	Redundant (8d) Handling-HS and midsagittal axis
ASL	167 (0.64)	6 (0.02)	29 (0.11)	58 (0.22)
BSL	114 (0.57)	7 (0.04)	26 (0.13)	53 (0.27)
HKSL	103 (0.55)	6 (0.03)	22 (0.12)	56 (0.30)
LIS	129 (0.54)	10 (0.04)	29 (0.12)	70 (0.29)
Average	128 (0.575)	7 (0.035)	27 (0.12)	59 (0.27)

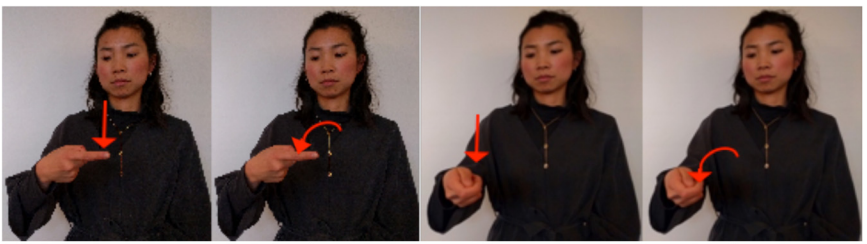

Figure 8: Structure and average proportion of handshape + movement combinations: (a) Object handshape (O-HS) + lateral axis; (b) O-HS + midsagittal axis; (c) handling handshape (H-HS) + lateral axis; (d) H-HS + midsagittal axis. The forms in (a) and (d) are redundant for agency in handshape type and movement axis; the forms in (b) and (c) are non-redundant.

prefer the same value for agency in handshape and movement (handling handshape + midsagittal movement, or object handshape + lateral movement).

The distributions of handshape-movement axis combinations are shown in Table 4, and the four possible combinations of the two handshape types (handling, object) and two movement axes (midsagittal, lateral) are exemplified in Figure 8. All combinations of handshape and movement axis are attested in each of the four sign languages, demonstrating that these features are fully combinatorial. However, as the findings in Sections 4.1.1, and 4.1.2 suggest, some combinations are more frequent in these descriptions. Since handshape type and movement axis both mark the agentive status of an event, these features have the potential to be combined in either a *redundant* relationship—with handshape type and movement axis in a verb encoding the same agentive information—or a *non-redundant* relationship—with handshape type and movement axis in a single verb encoding different agentive information. Recall from the Introduction that less redundancy makes the receiver's task more effortful, and more redundancy makes the receiver' task less effortful.

The redundant combinations of features are verbs with an object handshape + lateral movement axis (both features mark an event with no human agent, Figure 8a), and verbs with a handling handshape + midsagittal movement axis (both features mark an event with a human agent, Figure 8d). The non-redundant combinations of features are verbs with an object handshape (marking an event without an agent) and a midsagittal axis (marking an event with an agent), shown in Figure 8b, or verbs with a handling handshape (marking an agentive event) and a lateral movement axis (marking an event without an agent), shown in Figure 8c.

Signers produce verbs with redundant agent information in handshape and movement axis much more frequently than verbs with non-redundant information, as shown in Table 4 and Figure 9. This is consistent across languages (0.84–0.85 of all verbs across all four languages). Even though all languages have relatively few non-redundant forms (on average 15% of the total), we might ask what motivates non-redundant forms to occur in order to better understand the competing pressures at work in these structures.

We suggested in Sections 4.1.1 and 4.1.2 that object handshapes, lateral movements, and verbs without repetition may be "default" forms that lack a specification for agency and number, respectively, and we might expect that they occur equally frequently, but they do not. We see that handling + lateral forms are produced much more frequently (Figure 8c, 12%) than object + midsagittal forms (Figure 8b, 3.5%). Since the default, lateral axis appears more frequent in non-redundant forms, this suggests that, in addition to a preference for a single *sign* to have a single morphological value for agency, there may also be a preference to constrain the number of morphemes in the *movement*, which we explore in the next section in the analysis of repetition.

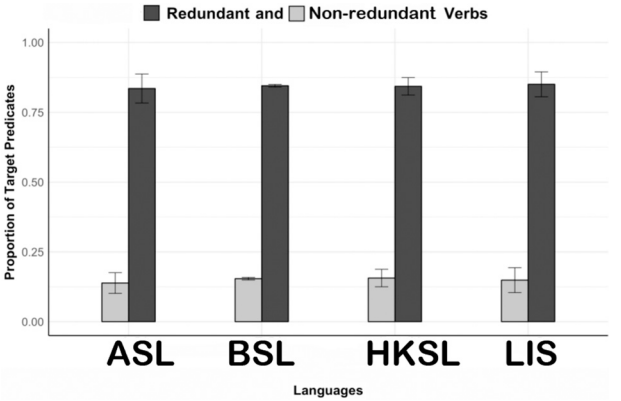

Figure 9: Average rates of verbs across languages that have redundant (dark grey bars) and non-redundant (light grey bars) agentive marking in handshape and movement axis. Error bars represent standard errors.

4.3 Combinations of handshape type, movement axis, and movement repetition in verbs

The analysis of redundant agent marking in the preceding section suggests that, despite the potential simultaneity available in the visual modality, there is a contravening preference for simpler, more redundant forms at the level of the verb (i.e., the same value for agency on handshape and movement). In the previous section, we reported that non-redundant handling + lateral verbs are more frequent than non-redundant object + midsagittal verbs. We therefore ask if non-redundant forms might be a consequence of the addition of movement repetition in the verb; in other words, there may also be a constraint on the number of morphemes per *movement*, thereby favoring the lateral movement axis in combinations with repetition.

We suggest that the lateral movement axis and object handshape type are "default" forms, potentially unmarked for agency and number (see Sections 4.1.1 and 4.1.2). We now consider how the addition of movement repetition affects the frequency of verbs with a lateral movement axis and verbs with an object handshape. If the addition of movement repetition triggers different patterns of lateral movement and object handshape combinations, this would suggest that there is a constraint at the level of the parameter (i.e., movement), as well as the sign. In Figure 10, we compare the distribution of verbs with a lateral movement axis with

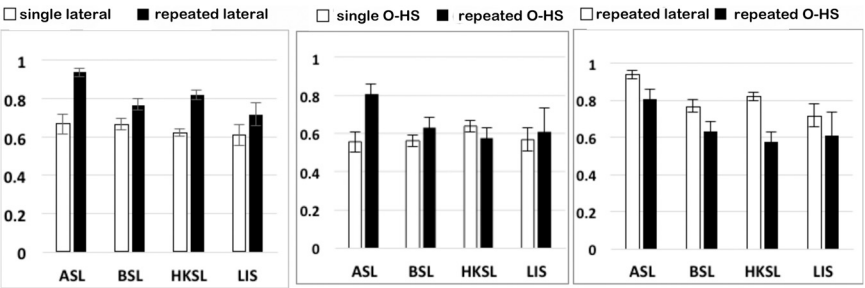

Figure 10: (a) The proportion of verbs produced with a lateral axis in single (white bars) and repeated forms (black bars); (b) the proportion of verbs produced with an object handshape (O-HS) in single (white bars) and repeated forms (black bars); (c) the comparison of repeated forms with a lateral movement (white bars) vs. those with an O-HS (black bars).

and without movement repetition (10a), and verbs with an object handshape with and without movement repetition (10b).

In 10a, we see that verbs with a lateral movement axis are produced significantly more often with repeated movements than with single movements (Mann Whitney U test of ranked averages: $n_2 = 4$; $U = 0$; $p < 0.05$). This pattern is not found for object handshapes combined with repeated versus single movements (Figure 10b; Mann Whitney U test of ranked averages: $n_2 = 4$; U = 3; $p = 0.10$) In 10c, the two "default" forms (object handshape and lateral movement axis) are compared with one another (*lateral axis* + repetition, drawn from 10a, and *handshape type* + repetition, drawn from 10b). We find significantly more lateral movement + repetition combinations than object handshape + repetition combinations (Mann Whitney U test of ranked averages: $n_2 = 4$; U = 2, $p < 0.05$).

A preference for the lateral axis + repetition might occur for morphological or phonological reasons. A morphological motivation restricts the number of morphemes per movement to one. In this case, a non-redundant form with a handling handshape (agent) + lateral movement expresses agency via the handshape type alone, and plurality on movement via repetition. Alternatively, a phonological motivation suggested in Section 4.1.2 is that lateral movements are articulatorily simpler, requiring one joint instead of two joints. Sideways repetition adds an additional joint—a shoulder joint—thus midsagittal, repeated movements would require three joints, while lateral, repeated movements require only two. Pfau and Steinbach (2005, 2006) also suggest a perceptual motivation against repeated, midsagittal movements: when combined with sideways repetition a midsagittal movement disrupts the flow of the sideways direction because they are body-anchored. All of these motivations would result in the same pattern, so unfortunately we cannot tease them apart without additional diagnostics.

Repetition is a crucial piece in this analysis because it reveals crosslinguistic differences in the patterns in the expression of agency and number. The crosslinguistic variation expressed in Figure 11 demonstrates a language's preference for expressing agent marking non-redundantly on the verb (the sign) via handshape *or*

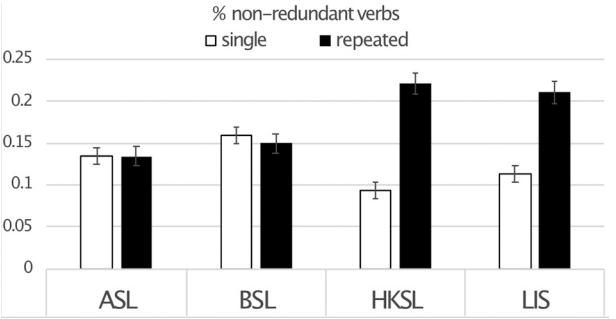

Figure 11: The average proportion of non-redundant agentive marking across the four sign languages in single (white bars) and repeated forms (black bars), with standard error indicated.

movement (rather than handshape *and* movement), in verbs with and without repetition. Allowing handshape alone to mark agency allows a "default" lateral movement form to combine with repetition. Even though the numbers of non-redundant forms are small, and can only be suggestive (the differences in Figure 11 between single and repeated predicates are not statistically significant), we see that non-redundant verbs are *more likely* to be repeated verbs in HKSL and LIS, but non-redundant verbs in ASL and BSL are *equally likely* to be single or repeated verbs.[12] Crosslinguistic differences are taken up again in Section 4.4.

Summing up the results so far, we find several important, common patterns across all four sign languages in the way that the three iconic properties under investigation behave in single verbs. First, in all four sign languages, handling handshape type and midsagittal movement axis are reliable markers of agency, and repetition is a reliable marker for number marking. Both movement axes and both handshape types are combinable with repetition. There is a preference to combine movement repetition with a the "default" movement axis (lateral), but there is not a parallel preference to combine movement repetition with the "default" handshape type (object).

All four languages have more verbs with redundant than non-redundant agent marking; however, in combinations with repetition, HKSL and LIS allow more non-redundant forms than ASL and BSL. Thus, based on the results presented thus far, when agency and plurality both need to be expressed, two possible solutions are available to languages. One solution, seen in HKSL and LIS, is to produce a single verb predicate (svVP) with a handling handshape to convey the agentive meaning, a lateral movement (default form), and repetition (for plural). This strategy leads to

12 In the entire data set there is only one form that is incongruent with repetition of the form [object handshape + midsagittal axis] + repetition.

more simultaneity, since plural and agent are in a single verb, but less redundancy because the same value for agency is not expressed on handshape and movement. The other solution, seen in ASL and BSL, is to produce a multiple verb predicate (mvVP): one verb with a handling handshape and midsagittal movement (redundant agency), and a second verb having lateral movement and repetition (plural). The distribution of multiple verb structures is discussed in the next section.

4.4 Agentive and number marking in verb phrases (VPs)

In this section, we analyze verb phrases (VPs), rather than individual verbs, in order to understand how signers construct descriptions within the VP and utterance. We analyze 501 utterances (122 ASL utterances, 124 BSL utterances, 127 HKSL utterances, and 128 LIS utterances).[13] In their descriptions, signers could produce a single-verb VP (svVP), multiple-verb VP (mvVP) or multiple VPs (VP+) in their description, as described in Section 3.4. In Figure 12 we contrast svVPs (black bars) versus multiple verb forms (mvVPs and VP+s, white bars) across the four conditions in the four target languages.[14] For all languages the percentage of mvVPs of the total utterances follows this cline: no-agent, single (avg. 25%) < no-agent, plural (avg. 33%) < agent, single (avg. 45%) < agent plural; average (avg. 71%).

There are relatively few mvVPs in the single no-agent trials (average 25%). Multiple verb VPs in single no-agent trials are not used to express agency or plurality; typically the second verb expresses the specific orientation of the object. In these utterances, one classifier in the mvVP will be a default form and another will show a specific orientation. We see somewhat more mvVPs in the multiple no-agent trials, particularly in ASL and LIS (Figure 12, top right, average 33%); most of these mvVPs are either: (1) redundant combinations of object handshape + lateral axis; V1 is a verb with no movement repetition, and V2 has repetition (Figure 13, top middle); or (2) multiple svVP forms in a sequence of VP+ forms (Figure 13, top right). In the latter case, there are intervening modifiers between each single sign production (e.g., [BLUE + "verb"]$_{VP}$, [TALL + "verb"]$_{VP}$).

Moving further up the cline, there are more mvVPs descriptions in response to agent, single trials (45%; see Figure 12, bottom left). With few exceptions, these mvVP structures are redundant combinations of a single handling

13 All signers responded to all vignettes: 32 items × 16 signers = 512 descriptions; however, in some cases, signers produced only a lexical label for the item in the vignette (e.g., if they saw a still image of a toy airplane, they produced only the lexical sign for AIRPLANE). These items thus do not have a verb and were excluded.

14 The multi-verb predicates in this table include verbs that may have additional information that is not solely agentive and plural, such as orientation of the object (upright or upside down).

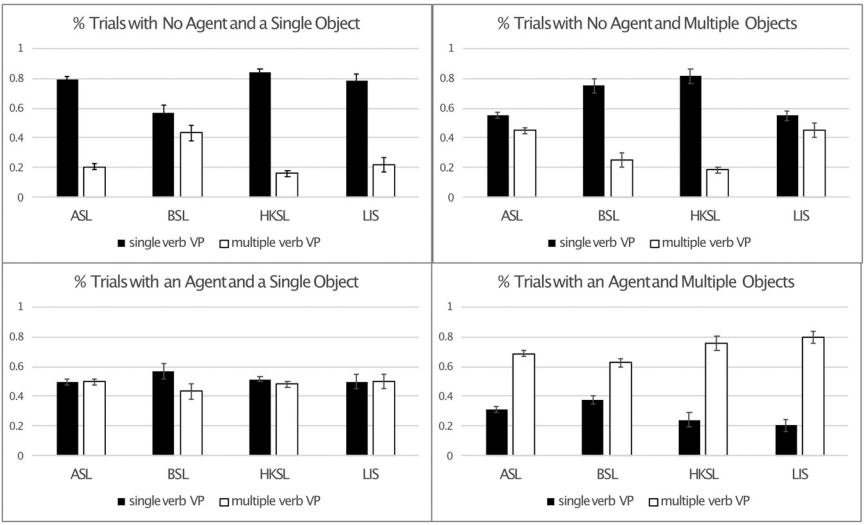

Figure 12: The proportion of single-verb VPs (svVPs white bars) and multiple-verb structures (black bars)—both multiple-verb VPs (mvVPs) and multiple VPs (VP+)—in descriptions of the four kinds of items in the study: No agent, single (top, left), no agent, plural (top, right), agent, single (bottom, left), and agent, plural (bottom, right).

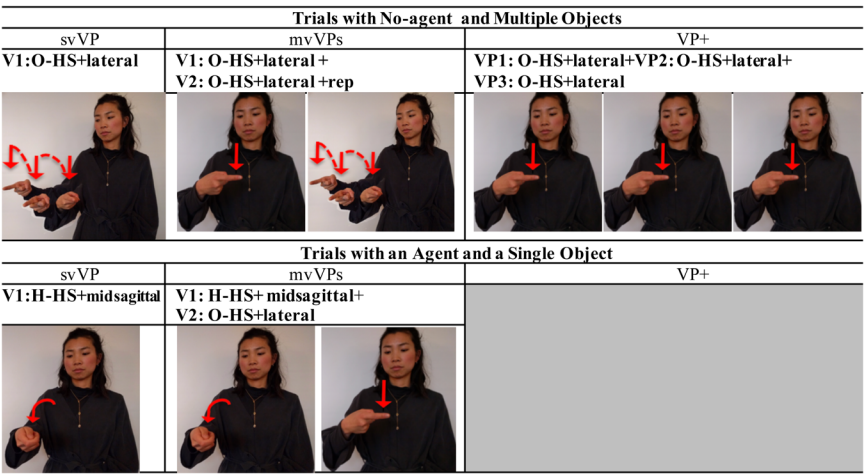

Figure 13: Structures of multiple-verb VPs (mvVP) and multiple VP forms (VP+) produced in no-agent plural contexts (top), and in agent, single contexts (bottom).

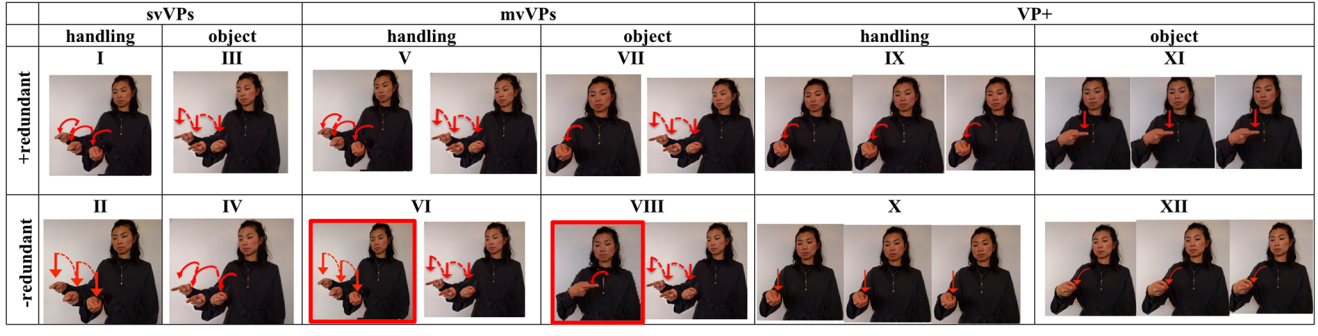

Figure 14: Examples of structures used in descriptions in response to agent, plural vignettes (the combinations in V–IX most commonly appear in the order shown, but may also appear in the reverse order). The Roman numerals correspond to those in Table 5. The cells outlined in red in VI and VIII show the non-redundant structure.

Table 5: Number of predicates for each language produced in each VP type (I–XII, Figure 14 and (3)) in agent-plural descriptions: single-verb VPs (svVPs), multiple-verb VPs (mvVPs), and multiple VPs (VP+s). ±R refers to redundancy of agent marking.

	svVPs					**mvVPs**					**VP+**				
	Handling		**Object**		**Total**	**Handling**		**Object**		**Total**	**Handling**		**Object**		
	+R	-R	+R	-R		+R	-R	+R	-R		+R	-R	+R	-R	
	I	**II**	**III**	**IV**		**V**	**VI**	**VII**	**VIII**		**IX**	**X**	**XI**	**XII**	**Total**
ASL	0	5	5	0	**10**	0	6	5	2	**13**	7	0	1	0	**8**
BSL	6	3	6	4	**19**	3	0	3	0	**6**	6	0	0	0	**6**
HKSL	6	6	1	6	**19**	2	5	2	1	**10**	0	2	0	0	**2**
LIS	7	3	0	10	**20**	3	4	1	3	**11**	0	1	0	0	**1**

handshape + midsagittal verb, followed by a single object handshape + lateral verb (illustrated in Figure 13, bottom, middle).

We now turn to the 125 descriptions associated with agent, multiple vignettes (31 in ASL, 31 in BSL, 31 in HKSL, and 32 in LIS) that the signers produced; 75% were mvVPs. The agent, multiple context is the only one in which + agent morphology and + plural morphology are expected to combine. In this condition, we find more structural variation in VPs across languages than in the other conditions, and thus we can more clearly observe competing pressures on the system. There are 12 structural types that appear in the descriptions of multiple/agent vignettes; examples are provided in Figure 14 and described in (3). From now on we refer to the number of trials, not percentages, since the numbers are quite small. Their distribution across languages is shown in Table 5. Redundant structures are assigned odd numbers (I, III, V, VII, IX, XI), and non-redundant structures are assigned even numbers (II, IV, VI, VIII, X).

(3) Structures used to describe multiple/agent vignettes across the four target languages

a. Single verb in a verb phrase (svVPS)

I.	(redundant)	handling handshape, midsagittal movement, repetition
II.	(non-redundant)	handling handshape, lateral movement, repetition
III.	(redundant)	object handshape, lateral movement, repetition
IV.	(non-redundant)	object handshape, midsagittal movement, repetition

b. multiple verbs in a verb phrase (mvVPs)

V.	(redundant)	V1: handling handshape, midsagittal movement, repetition V2: object handshape, lateral movement, repetition
VI.	(non-redundant)	V1: handling handshape, lateral movement, repetition V2: object handshape, lateral movement, repetition
VII.	(redundant)	V1: handling handshape, midsagittal movement, no-repetition V2: object handshape, lateral movement, repetition
VIII.	(non-redundant)	V1: handling handshape, lateral movement, no-repetition

c. multiple verb phrases (VP+)

IX.	(redundant)	V1,2,3: handling handshape, midsagittal movement, no repetition
X.	(non-redundant)	V1,2,3: handling handshape, lateral movement no repetition
XI.	(redundant)	V1,2,3: object handshape, lateral movement, no-repetition
XII.	(non-redundant)	V1,2,3: object handshape, midsagittal movement no-repetition

Any discussion of the crosslinguistic differences can only be suggestive with so few data points in each cell; nonetheless, the high degree of control we have placed on the context, as seen in all of the other findings we have presented thus far, allows us to have some confidence that the crosslinguistic differences are reliable. Across languages, we see that BSL, HKSL and LIS prefer svVP structures, but ASL prefers mvVPs and VP+ structures.

5 An analysis of VP variation using Optimality Theory

In this section, we provide an Optimality Theoretic (OT) analysis that captures the differences across sign languages discussed in Section 4.4. The set of five constraints we employ in the analysis are given in Table 6. All of these constraints can be violated, as is customary in Optimality Theory. They capture pressures observed across all of the languages in the study, and their differential ranking serves to capture variation across languages (Boersma and Hayes 2001; Prince and Smolensky 1993).

FAITH:ARG and FAITH:PL pertain to the morphology of the form, requiring that the agency and plurality of the event, respectively, be expressed within a single VP. SIMULTANEITY, REDUNDANCY and *MID+REP pertain to both the morphology and phonology of the forms.

SIMULTANEITY requires forms to package all morphology within a single verb. This makes forms more efficient (i.e., shorter duration), but may be more effortful both for the speaker to produce and for the listener to comprehend because several morphemes must be produced and processed at once. *MID+REP prohibits midsagittal axis (agent) and repeated movements (plural) from combining within a single verb, either for morphological reasons—to

Table 6: Constraints capturing the variation in descriptions of multiple/agent vignettes. The Roman numerals refer to the VP structures illustrated in Figure 13.

Constraint (C)		obeys C	violates C
a.	SIMULTANEITY: Verbal morphology must occur simultaneously in a single verb.	I–IV	V–XII
b.	*MIDSAGITTAL+REPEAT: A movement produced in the midsagittal plane may not be repeated.	II, III, VI, VII, VIII, X, XI	I, IV, V, IX, X
c.	REDUNDANCY: Agentive features of handshape and movement must agree.	Odd numbered kinds	Even numbered kinds
d.	FAITH:ARG: all arguments in an event must be represented in the morphology of the VP.	I, II, IV–X, XII	III, XI
e.	FAITH:PLURAL: plural events must be represented in the morphology of the VP.	I–VIII	IX–XII

block two morphological values in a single movement—or for phonetic/phonological reasons (because these movements are articulatorily complex, as described in Section 4.3).

REDUNDANCY requires that the two expressions of agency match in their value (handshape type and movement axis must both be +agentive or –agentive), as shown in Figure 8. Recall from the Introduction that less redundancy makes the receiver's task more effortful, and more redundancy makes the receiver's task less effortful; we therefore ask if each language has a stronger or weaker preference for redundancy. A strong preference for redundancy would be likely to result in using a mvVP form to describe multiple/agent vignettes because the agent meaning is marked on both the movement (i.e., midsagittal axis), and the handshape (i.e., handling handshape) in one verb, and the plural (repetition) occurs on the second verb. Recall that there is also a dispreference for forms with a midsagittal axis and movement repetition, which might also lead to more mvVPs. A weak preference (or lack of preference) for redundancy would allow handshape and movement to have different values for agency; thus plurality could be expressed on the same verb as the agent (svVP).

This OT analysis shows how the constraints are ranked across the four sign languages. The rankings for each language, based on the number of violations of each constraint in descriptions of multiple/agent vignettes, are given in (4).

(4) Constraint Rankings (number of violations in the data is given in parentheses)

	High-ranked Cs	**Low-ranked Cs**
ASL	(4) *MID+REP > (7) REDUNDANCY > (8) FAITH:ARG, FAITH:PL > (20) SIMULTANEITY	
BSL	(6) FAITH:ARG, FAITH:PL > (7) REDUNDANCY > (9) SIMULTANEITY > (16) *MID+REP	
HKSL	(0) FAITH:ARG > (2) FAITH:PL > (8) SIMULTANEITY > (11) REDUNDANCY > (17) *MID+REP	
LIS	(1) FAITH:PL > (3) FAITH:ARG > (9) SIMULTANEITY > (10) REDUNDANCY > (16) *MID+REP	

There are two tendencies that are common across the four sign languages. First, FAITH:ARG and FAITH:PL(URAL) travel together across all four sign languages; that is, both have a similar number of violations (±2). Second, FAITH:ARG and FAITH:PL outrank SIMULTANEITY across all of the sign languages, so integrity of meaning (making sure that argument information and number information are represented in the VP) is a powerful motivation at the VP level.

Crosslinguistic differences exist as well. First, ASL patterns most differently from the other three languages. Unlike the other sign languages, ASL has fewer svVPs (I–IV) than mvVPs/VP+s (V–XII in Table 5). The OT analysis captures this observation by placing SIMULTANEITY as bottom-ranked and *MID+REP as top-ranked in ASL. Second, recall from Figure 11 that HKSL and LIS were more tolerant of forms that are non-redundant (II, IV, VI, VIII, X, XII in Table 5), particularly in repeated forms. This observation is captured by REDUNDANCY being low-ranked, the second to last constraint in both of these languages; REDUNDANCY is ranked higher in both ASL and BSL. We also see that, generally, HKSL and LIS are very similar to one another in their rankings.

Summarizing the analysis of VPs in agent plural trails, we find that there are some similarities in VPs across the four target languages; however, we also see crosslinguistic variation in the ranking of constraints on plural and agentive morphology. The pressures on form are present in all of the languages, but they are prioritized differently. Prior literature on sign language morphology has emphasized the capacity of sign languages for complex, simultaneously produced morphology. It would be possible (and grammatical) for signers to describe all of the events in the stimulus vignettes using a single verb (I–IV). While svVPs do occur, there is crosslinguistic variation in the ways that svVPs, mvVPs, and VP+s are used. Three of the four languages favor single verb forms in which all morphology is simultaneously layered within a single verb (BSL, HKSL, LIS); in contrast, ASL strongly prefers repetition to combine with lateral movements, which results in mvVPs or VP+s.

The constraints proposed in the OT analysis here were designed to capture crosslinguistic variation in descriptions of agent multiple vignettes, when both

agent and plural values are required to fully describe the vignettes presented; however, we would like to briefly comment on the patterns observed in the other three conditions—for single/no-agent, multiple/no-agent, and single/agent trials. With regard to redundancy, the numbers of non-redundant forms in all conditions are small (average of 10% across languages and conditions), and those in the single no-agent, multiple/no-agent, and single/agent trials are neglible (<3%). Non-redundancy is therefore most often seen when a both agent and plural are represented in the predicate. Regarding single versus multiple verbs, recall that the frequency of mvVPs decreases from 75% in agent, plural trials to 45% in agent, single trials, to 33% in no-agent, plural forms, to 25% in no-agent, single trials. Thus the necessity to represent agency appears to trigger a second verb more often than the necessity to represent plural. We leave this issue to future work.

6 General discussion

In this section, we discuss the similarities and differences across the four languages and the possible iconic, morphological, phonological and cognitive motivations for the results and analyses that have just been presented. We suggest that iconicity and conventionalization are important motivations for the similarity among languages that we see in single verbs, due to the common iconic raw material employed, along with conventionalization due to phonological (*MID+REP) and cognitive constraints (REDUNDANCY). We also suggest that grammatical organization revealing crosslinguistic variation is more apparent in verb phrases. The crosslinguistic variation found at the VP level demonstrates that iconic, morphological, phonological and cognitive motivations can be prioritized differently across languages; thus all of these motivations are intertwined. We also consider the implications of our results for the representation of person morphology, particularly how it might bear on the issue of the emergence of agreement systems.

6.1 Crosslinguistic similarities

In the analysis of *single verbs* (Sections 4.1–4.3), we see that the four unrelated sign languages we sampled have similar distributions of handshape and movement properties, which appear to have similar iconic, phonetic/phonological, and

cognitive bases. The iconicity deployed in the meanings analyzed here (agency and plurality) are expressed using the same phonological features in all four target languages. Sections 4.1–4.3 demonstrate that all four languages use hand-as-hand iconicity and a migsagittal movement axis with body anchoring to represent agency. All four languages also use movement repetition to represent plurality. Since formal diagnostics have been done to establish morphological status only for handshape, we cannot be certain about the morphological status of movement axis and repetition, but we suggest that these iconic patterns are likely to rise to the level of morphology because they are highly productive, categorical, and systematic.

The combinations of these three properties at the level of the verb show many similarities across languages as well. All four languages show a preference for redundant expression of agency in handshape and movement axis, and all four languages have the same rankings regarding the frequency of various combinations of these properties within a single verb (Table 4). This distribution may be partially motivated by Pfau and Steinbach's (2005, 2006) proposed phonological prohibition on combinations of sideways repetition and movements with a midsagittal axis, because midsagittal movements involve body-anchoring.

We suggest another reason for the pattern, which is articulatory in nature– namely, a movement in the lateral axis involves only the elbow when produced singly, whereas midsagittal movements require two joints for single movements (wrist + elbow or elbow + shoulder). The addition of sideways repetition increases the complexity of the movement further. It has been shown in both ASL (Brentari 1998) and Finnish Sign Language (Jantunen 2007; Jantunen and Takkinen 2010) that movements with three joints are rare. In other words, a preference for articulatorily simple movements may extend beyond the core vocabulary to the classifier system.

We also find some important similarities across the four languages at the level of the *verb phrase*. As mentioned in Section 5, the constraints FAITH:ARG and FAITH:PL(URAL) travel together across all four sign languages, and FAITH:ARG and FAITH:PL outrank SIMULTANEITY across all of the sign languages. These two facts suggest that the integrity of meaning (making sure that argument information and number information are represented in the VP) is a powerful motivation at the VP level.

6.2 Crosslinguistic variation

We see preliminary hints of crosslinguistic variation at the single verb level in Figure 10. In verbs with movement repetition, HKSL and LIS allow more agentive non-redundancy at the verb level than the other two languages; however, these

results are based on a small number of data points and will need to be replicated in future work. This section therefore focuses on the VP unit. We see in Table 5 that the four sign languages in this study differ in their preferences for expressing agency and plurality at the level of the VP. ASL prefers simpler, more redundant (with respect to agency) mvVPs or VP+ structures, whereas the other three sign languages prefer more complex simultaneous svVPs.

We propose a cognitive explanation for the preference for redundant forms generally, and for the ASL data at the VP level. In sign languages, particularly in classifier constructions, it is common that some individual features can be isolated as morphemes (i.e., they are compositional, as shown in Figure 1). The multi-morphemic meanings that occur in many spoken languages also carry multiple meanings, but the forms that carry each meaning are not isolable (i.e., they are fusional). In the following spoken language examples, all multiple morphemes are packaged in a single segment or syllable (5)–(9). Consider their fusional nature alongside the ASL form in Figure 1 with four compositional morphemes.

(5) English *has* (***-s*** is associated with 3 morphemes, 1 syllable)
He **has** left
3-sg-past
"He has left."

(6) Italian *li* (-***li*** is associated with 3 morphemes; 1 syllable Cardinaletti and Giusti 2001),
Magne **-li**?
3-pl-subject
"Do they eat?"

(7) Basque ***-o*** (***-o*** is associated with 3 morphemes, 1 syllable; Gaminde 2000: 303)
Eusi- /0 i- ten do -o -tze **-o** baye
3-sg-erg
"It barks at him, though."

(8) Meskwaki *-i* (***-i*** is associated with 7 morphemes, 1 syllable; Jones and Michelson 1911)
wâpam **-i**!
2-sg-subj; 3-animate-obj; imperative
"[You], Look at him/her/them (animate)!"

(9) Hungarian *-d* (***-d*** is associated with 7 morphemes, 1 syllable; Kleiber et al. 2016)
lás **-d**!
see **2-sg-subj;3-definite-obj; subj (or imperative)**
"You should/may see him/her/it/them"; also the command "[You] see him/her/it/them!"

These examples illustrate that spoken languages also combine several morphemes within a single unit, but often do so in fusional, rather than agglutinative, ways (Geraci 2018; Santoro 2018). What makes sign languages special is the isolable nature of their morphological forms, not the sheer number of morphological categories, encoded within a single unit. What we suggest is that the productive, recombinable, and simultaneous nature of sign language morphology may come with processing costs. The spoken language, fusional morphology of examples (5)–(9) may not incur such costs; we plan to explore this difference between signed and spoken languages experimentally in future work.

When the numbers of phonological and morphological constituents are not aligned in spoken and signed languages (e.g., 2 morphemes/1 syllable, as in (5), Eng. *has*, or as in Type II, Figure 14, a form with handling handshape + repeated lateral movement),[15] grammatical constraints, processing pressures, and patterns of use must all be considered, similar to liaison phenomena in French (Laks et al. 2018), flapping in American English (de Jong 1998), or /ay/ raising in Canadian English (Liberman 2018). In all of these cases, grammar cannot offer a single, elegant, comprehensive solution; instead these phenomena require more than one mechanism in order to fully explain them, mechanisms that involve both grammar and language processing.

6.3 The relationship between movement axis and person agreement morphology

Previous work (Horton et al. 2015) demonstrated, and the current study confirms, that midsagittal movements are associated with agentive morphology. We might therefore plausibly ask whether the midsagittal axis is related to person morphology. The human signer as subject is prioritized in midsagittal movements. These movements are not only midsagittal, but also body-anchored since the signer's body is one of the end points of the movement. As Padden (1988), Brentari (1988), and Meir et al. (1998, 2002) have argued, agreement morphology marks not

15 One sequential movement is equal to one syllable in sign languages (Brentari 1998).

only the persons involved in the event, but also the source and goal, which are spatial concepts. Relating to space and person morphology, it has been shown that the signer's body assumes the role of an animate third person in some cohorts of relatively young sign languages: Al-Sayid Bedouin Sign Language, Israeli Sign Language (Padden et al. 2010), and Nicaraguan Sign Language (Flaherty 2014). What we are proposing is that, although movements in classifier verbs can occur anywhere in neutral space, when the initial (or final) place of articulation is the signer's body along the midsagittal axis, it triggers a special kind of meaning that is interpreted as a human agent rather than a non-human agent. In future work, we plan to tease apart the animacy of the two arguments (animate/inanimate) from the type of axis (midsagittal/lateral) in a number of verb types, including transfer verbs (e.g., GIVE), act-on verbs (e.g., PUNCH), and additional spatial verbs. For example, we will be able to ask whether midsagittal movements are preferred with animate vs. inanimate agents (e.g., *The **boy** [vs. **ball machine]** threw the ball to the girl*). If human agents are treated differently from non-human agents when location and verb type are held constant, even in the classifier system, the choice of movement axis may be the beginning of an agreement system based on animacy. Such a pattern would suggest that classifier forms with an agent may be similar to transfer verbs, and may be ultimately tied to the person agreement system in sign languages.

7 Conclusions

In this paper, we have described the distribution of three features of classifier predicates—handshape type, movement axis, and movement repetition–in four sign languages. Both handshape (handling) and movement axis (midsagittal) are used to mark *agency*, and repetition is used to mark *plurality* in all four languages at the level of the single verb. At the level of the verb phase we proposed a set of Optimality Theoretic constraints that capture the similarities and differences across languages in response to several pressures exerted on these forms in all four languages: the pressure to be complete (FAITH:ARG and FAITH:PL), the pressure to be efficient (SIMULTANEITY), and the pressure to be redundant (REDUNDANCY). The differential ranking of constraints captures a language's preference for single-verb VPs or multiple-verb (sequential) VPs. We conclude that the patterns of distribution in forms used to describe an agent acting on multiple objects is motivated by iconicity, phonology, morphology, and cognition, and these common pressures are differentially ranked across the four target languages in this study.

References

Allan, Keith. 1977. Classifiers. *Language* 53(2). 285–311.

Aronoff, Mark, Irit Meir & Wendy Sandler. 2005. The paradox of sign language morphology. *Language* 81. 301–344.

Ashby, W. Ross. 1965. *An introduction to cybernetics*. New York: John Wiley.

Benedicto, Elena & Diane Brentari. 2004. Where did all the arguments go?: Argument-changing properties of classifiers in ASL. *Natural Language and Linguistic Theory* 22(4). 743–810.

Boersma, Paul & Bruce Hayes. 2001. Empirical tests of the gradual learning algorithm. *Linguistic Inquiry* 32. 45–86.

Brentari, Diane. 2019. *Sign language phonology*. Cambridge, UK: Cambridge University Press.

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

Brentari, Diane. 1988. Backwards verbs in ASL: Agreement re-opened. In Diane Brentari, Gary Larson & Lynn MacLeod (eds.), *Papers from the 24th annual meeting of the Chicago Linguistic Society*, 16–26. Chicago: Chicago Linguistic Society.

Brentari, Diane, Marie Coppola, Pyeong-Whan Cho & Ann Senghas. 2016. Handshape complexity as a pre-cursor to phonology: Variation, emergence, and acquisition. *Language Acquisition* 24(4). 283–306.

Brentari, Diane, Alessio Di Renzo, Jonathan Keane & Virginia Volterra. 2015a. Cognitive, cultural, and linguistic sources of a handshape distinction expressing agentivity. *Topics* 7. 95–123.

Brentari, Diane, Chiara Branchini, Fenlon Jordan, Laura Horton & Gladys Tang. 2015b. Typology in sign languages: Can it be predictive? In Ksenia Ershova, Joshua Falk & Jeffrey Geiger (eds.), *Proceedings from the 51st annual meeting of the Chicago Linguistics Society*, 47–65. Chicago: Chicago Linguistic Society.

Brentari, Diane, Marie Coppola, Ashley Jung & Susan Goldin-Meadow. 2013. Acquiring word class distinctions in American Sign Language: Evidence from handshape. *Language Learning and Development* 9(2). 130–150.

Brentari, Diane, Marie Coppola, Laura Mazzoni & Susan Goldin-Meadow. 2012. When does a system become phonological? Handshape production in gesturers, signers, and homesigners. *Natural Language and Linguistic Theory* 30(1). 1–31.

Brentari, Diane & Carol Padden. 2001. A language with multiple origins: Native and foreign vocabulary in American Sign Language. In Diane Brentari (ed.), *Foreign vocabulary in sign language: A cross-linguistic investigation of word formation*, 87–119. Mahwah, NJ: Lawrence Erlbaum Associates.

Brown, Robert. 1981. Semantic aspects of some Waris predications. In Karl James Franklin (ed.), *Syntax and semantics in Papua New Guinea Languages*, 93–123. Ukarumpa: Summer Institute of Linguistics.

Cardinaletti, Anna & Giuliana Giusti. 2001. Semi-lexical motion verbs in Romance and Germanic. In Norbert Corver & Henk van Riemsdijk (eds.), *Semi-lexical categories: The function of content words and the content of function words*, 371–414. Berlin/New York: Mouton De Gruyter.

Colby, Benjamin. 1958. Behavioral redundancy. *Behavioral Science* 3. 317–322.

Coppola, Marie, Elizabeth Spaepen & Susan Goldin-Meadow. 2013. Communicating about quantity without a language model: Number devices in homesign grammar. *Cognitive Psychology* 67. 1–25.

Crasborn, Onno & Han Sloetjes. 2008. Enhanced ELAN functionality for sign language corpora. In *Proceedings of LREC 2008, sixth international conference on language resources and evaluation*.

de Jong, Kenneth. 1998. Stress-related variation in the articulation of coda alveolar stops: Flapping revisited. *Journal of Phonetics* 26(3). 283–310.

Emmorey, Karen. 2002. *Language, cognition and the brain*. Mahwah, NJ: Lawrence Erlbaum.

Emmorey, Karen. 2003. *Perspectives on classifier constructions in sign languages*. Mahwah, NJ: Lawrence Erlbaum Associates.

Engberg-Pedersen, Elisabeth. 1993. *Space in Danish Sign Language: The semantics and morphosyntax of the use of space in a visual language*. Hamburg: Signum.

Ergin, Rabia & Diane Brentari. 2017. Handshape preferences for objects and predicates in central Taurus sign language. In M. LaMendola & J. Scott (eds.), *Proceedings of the 41st annual Boston University Conference on Language Development (BUCLD)*, 222–235. Somerville, MA: Cascadilla Press.

Fischer, Susan. 1973. Two processes of reduplication in the American Sign Language. *Foundations of Language* 9. 469–480.

Fischer, Susan & Bonnie Gough. 1978. Verbs in American Sign Language. *Sign Language Studies* 18. 17–48.

Flaherty, Molly. 2014. *The emergence of argument structure in Nicaraguan Sign Language*. Doctoral dissertation. University of Chicago.

Geraci, Carlo. 2018. *Good question, right method, reasonable answer.vKeynote presentation at the Conference on Formal and Experimental Approaches to Sign Language*. Venice, Italy.

Gaminde, Iñaki. 2000. *Zamudio berbarik berba*. Bilbo: Labayru Ikastegi.

Goldin-Meadow, Susan, Diane Brentari, Marie Coppola, Laura Horton & Ann Senghas. 2015. Watching language grow in the manual modality: Nominals, predicates and handshapes. *Cognition* 136. 381–395.

Goldin-Meadow, Susan & Diane Brentari. 2017. [Target article] Gesture, sign and language: The coming of age of sign language and gesture studies. *Brain and Behavioral Sciences* 40. 1–60.

Goldwater, Sharon & Mark Johnson. 2003. Learning OT constraint rankings using a maximum entropy model. In *Proceedings of the workshop on variation within optimality theory*, 111–120.

Hakgüder, Emre & Diane Brentari. 2018. The interplay between the PreVP and the classifier predicate in instrumental constructions. In *Poster presented at the annual meeting of the Linguistics Society of America*, Salt Lake City, January 4–7.

Hamanna, Silke, Diana Apoussidoub & Boersma Paul. 2012. Modelling the formation of phonotactic restrictions across the mental lexicon. In *Proceedings from the Chicago Linguistic Society*, Vol. 45, 193–206. Chicago: Chicago Linguistic Society.

Horton, Laura, Susan Goldin-Meadow, Marie Coppola, Ann Senghas & Diane Brentari. 2015. Forging a morphological system out of two dimensions: Agentivity and number. *Open Linguistics* 1. 596–613.

Hsia, H. J. 1977. Is it the lost key to better communication? *AV Communication Review* 25. 63–85.

Jantunen, Tommi. 2007. Tavu suomalaisessa viittomakielessa. [The syllable in Finnish Sign Language; with English abstract]. *Puhe ja kieli* 27. 109–126.

Jantunen, Tommi & Ritva Takkinen. 2010. Syllable structure in sign language phonology. In Diane Brentari (ed.), *Sign languages*, 312–331. Cambridge: Cambridge University Press.

Johnston, Trevor & Adam Schembri. 2007. *Australian Sign Language (Auslan): An introduction to sign language linguistics*. Cambridge: Cambridge University Press.

Jones, William & Truman Michelson. 1911. Fox. In Franz Boas (ed.), *Handbook of American Indian languages 1*, 735–873. New York: J. J. Augustin.
Kimmelman, Vladim. 2018. Reduplication and repetition in Russian Sign Language. In Rita Finkbeiner & Ulrike Freywald (eds.), *Exact repetition in grammar and discourse*, 91–109. Berlin: De Gruyter.
Kimmelman, Vladim, Pfau Roland & Enoch Aboh. 2020. Argument structure of classifier predicates in Russian Sign Language. *Natural Language & Linguistic Theory* 38. 539–579.
Kleiber, Judit, Gábor Alberti & Veronika Szabó. 2016. The intensional profiles of five Hungarian imperative sentence types. *Linguistica* 56(1). 161–172.
Klima, Edward & Ursula Bellugi. 1979. *The signs of language*. Cambridge, MA: Harvard University Press.
Kyle, James & Bencie Woll. 1983. *Language in sign: An international perspective on sign language*. London: Croom Helm.
Laks, Bernard, Basilio Calderone & Chiara Celata. 2018. French liaison in the light of corpus phonology: From lexical information to patterns of usage variation. In Diane Brentari & Jackson Lee (eds.), *Shaping phonology*, 278–308. Chicago: University of Chicago Press.
Lane, Harlan. 1984. *When the mind hears*. New York: Random House.
Lau, Prudence. 2012. *Serial verb constructions in Hong Kong Sign Language*. Doctoral dissertation. Chinese University of Hong Kong.
Liberman, Mark. 2018. Toward progress in theories of language sound structure. In Diane Brentari & Jackson Lee (eds.), *Shaping phonology*, 201–222. Chicago: University of Chicago Press.
Loos, Cornelia. 2017. *The syntax and semantics of resultative constructions in Deutsche Gebärdensprache (DGS) and American Sign Language (ASL)*. Doctoral dissertation. University of Texas-Austin.
Mathur, Gaurav & Christian Rathmann. 2010. Two types of nonconcatenative morphology in sign languages. In Gaurav Mathur & Donna Jo Napoli (eds.), *Deaf around the world: The impact of language*. Oxford University Press.
Matthews, Peter. 1991. *Morphology*. Cambridge, UK: Cambridge University Press.
Mazzoni, Laura. 2008. *Classificatori e Impersonamento nella Lingua dei Segni Italiana*. Pisa: Plus, IT.
Meir, Irit. 2002. A cross-modality perspective on verb agreement. *Natural Language and Linguistic Theory* 20. 413–450.
Meir, Irit. 1998. Syntactic–semantic interaction in Israeli sign language verbs: The case of backwards verbs. *Sign Language and Linguistics* 1(1). 3–37.
Padden, Carol. 1988. *Interaction of morphology and syntax in American Sign Language*. New York: Garland.
Padden, Carol. 1998. The ASL lexicon. *Sign Language and Linguistics* 1: 39–60.
Padden, Carol, Irit Meir, Mark Aronoff & Wendy Sandler. 2010. The grammar of space in two new sign languages. In Diane Brentari (ed.), *Sign languages: A Cambridge language survey*, 570–592. Cambridge: Cambridge University Press.
Perniss, Pamela, Inge Zwitserlood & Asli Özyürek. 2015. Does space structure spatial language? A comparison of spatial expression across sign languages. *Language* 91. 611–641.
Pinna, Paola, Laura Pagliari Rampelli, Paolo Rossini & Virginia Volterra. 1993. Written and unwritten records from a residential school for the Deaf in Rome. In Renate Fischer & Harlan Lane (eds.), *Looking back*, 349–368. Hamburg, Germany: Signum Press.

Pfau, Roland & Markus Steinbach. 2005. Backward and sideward reduplication in German Sign Language. In Bossong Georg, Comrie Bernard & Yaron Matras (eds.), *Studies on reduplication*, 569–594. Berlin: Mouton De Gruyter.

Pfau, Roland & Markus Steinbach. 2006. Pluralization in sign and speech: a cross-modal typological study. *Linguistic Typology* 10. 135–182.

Pizzuto, Elena. 1987. Aspetti Morfo-syntattici. In Virginia Volterra (ed.), *La lingua italiana dei segni*, 179–209. Bologna: Il Mulino.

Prince, Alan & Paul Smolensky. 1993. *Optimality theory: Constraint interaction in generative grammar*. Technical report TR-2, New Brunswick, N.J: Rutgers Center for Cognitive Science, Rutgers University.

Reza, Fazlollah. 1991. [1961]. *An introduction to information theory*. New York: Dover [McGraw-Hill].

Santoro, Mirko. 2018. *Compounds in sign languages: The case of Italian and French Sign Language*. Doctoral dissertation. Paris: l'École des Hautes Études en Sciences Sociales.

Schick, Brenda. 1990. The effects of morphosyntactic structure on the acquisition of classifier predicates in ASL. In Ceil Lucas (ed.), *Sign language research: Theoretical issues*, 358–374. Washington, DC: Gallaudet University Press.

Supalla, Ted. 1982. *Structure and acquisition of verbs of motion and location in American Sign Language*. Doctoral dissertation. San Diego: UC-San Diego.

Supalla, Ted. 1990. Serial verbs of motion in ASL. In Susan Fischer & Patricia Siple (eds.), *Theoretical issues in sign language research: Linguistics*, Vol. 1, 127–154. Chicago, IL: University of Chicago Press.

Sze, Felix, Connie Lo, Lisa Lo & Kenny Chu. 2013. Historical development of Hong Kong Sign Language. *Sign Language Studies* 13(2). 155–180.

Wallin, Lars. 1994. *Polysynthetic signs in Swedish Sign Language*. Doctoral dissertation. Stockholm, Sweden: University of Stockholm.

Wilbur, Ronnie. 2009. Productive reduplication in a fundamentally monosyllabic language. *Language Sciences* 31. 325–342.

Wilbur, Ronnie, Edward Klima & Ursula Bellugi. 1983. Roots: The search for origins of signs in ASL. In *Proceedings from the 19th annual meeting of the Chicago Linguistic Society*, 314–336.

Woodward, James. 1993. Intuitive Judgments of Hong Kong Signers about the Relationship of Sign Language Varieties in Hong Kong and Shanghai. *CUHK Papers in Linguistics* 4. 88–96.

Zwitserlood, Inge. 2003. *Classifying hand configurations in Nederlandse Gebarentaal*. Leiden: The University of Leiden, The Netherlands Graduate School of Linguistics (LOT).

Zwitserlood, Inge. 2012. Classifiers. In Roland Pfau, Markus Steinbach & Bencie Woll (eds.), *Sign language: An international handbook*, 158–186. Berlin: Mouton De Gruyter.

Zwitserlood, Inge & Sibylla Nijhoff. 1999. Pluralization in sign language of the Netherlands. In Don Jan & Ted Sanders (eds.), *OTS yearbook, 1998–1999*, 58–78. Utrecht: Utrechts Instituut voor Linguistick OTS.