



SIGNON

Sign Language Translation Mobile Application and Open Communications Framework

Deliverable 3.3: Linguistic description for ISL, BSL, VGT, NGT and LSE



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Overview: This deliverable presents an overview of the linguistic research on the sign languages of our project. After analysing the gaps and needs the different teams of our consortium have focused on the topics of each language that have the highest impact for the translation process. Driven by the needs and requirements for linguistic insides to aid the translation we analysed sign languages focusing on constituent order, on gerund constructions, on contrasting older and younger generations of signers, on the impact of video-mediated conversations on (sign) language and on neologisms, depiction. We also developed the concept of SignNets which, similar to WordNets for words (spoken language / written form) are semantic networks of signs.

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| V0.1 | D3.3 | Adrián Núñez-Marcos | UPV/EHU | 19/12/2023 |
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| V0.1 | D3.3 | Rehana Omardeen | EUD | 19/12/2023 |
| V0.1 | D3.3 | Mirella De Sisto Dimitar Shterionov | TiU | 20/12/2023 |

Acronyms

The following table provides definitions for acronyms and terms relevant to this document.

| Acronym | Definition |
|--------------------------------|--|
| MT | Machine translation |
| SLMT | Sign language machine translation |
| VGT, NGT, ISL, LSE,BSL and ASL | Flemish, Dutch, Irish, Spanish, British and American Sign Language |
| LC | Location |
| LE | Located Element |
| SOV | Subject - object - verb |
| SVO | Subject - verb - object |
| SVOV | Subject - verb - object - verb |
| OSV | Object - subject - verb |
| OMW | Open Multilingual WordNet |
| STEM | Science Technology Engineering Math |
| SDGBV | Sexual, Domestic and Gender Based Violence |

Table of Contents

| | |
|---|-----------|
| 1. Introduction | 5 |
| 1.1 Linguistics and SLMT (how linguistics has informed and can inform SLMT) | 5 |
| 1.2 Deliverable structure | 7 |
| 2. Linguistic analysis of VGT, NGT, ISL, LSE and BSL | 8 |
| 2.1 Flemish Sign Language (VGT) | 8 |
| 2.1.1 Constituent Order in Flemish Sign Language | 8 |
| 2.1.2 The impact of video on sign language production and structure | 11 |
| 2.2 Sign Language of the Netherlands (NGT) | 15 |
| 2.3 Irish Sign Language (ISL) | 15 |
| 2.3.1 Neologisms in Irish Sign Language - Depiction as a Driver of Change | 15 |
| 2.3.2 Gerunds in Irish Sign Language | 19 |
| 2.4 British Sign Language | 22 |
| 2.4.1 Constituent order and topic-comment structure in BSL | 22 |
| 2.5 Spanish Sign Language | 23 |
| 2.5.1 Synthetic LSE glosses based on linguistic features visible in LSE glosses | 23 |
| 3. SignNets | 25 |
| 4. Conclusion | 28 |
| References | 30 |

1. Introduction

Text-to-text machine translation (MT) has advanced significantly over the last 70 years or so. Currently state-of-the-art results are achieved through end-to-end, data-driven approaches. For sign languages (SLs) such an approach is ineffective, with exception to limited use-cases and domains, due to the lack of sufficiently high volumes of quality data to build models from. At this stage of the development of automatic translation solutions to SL we need to focus on a better understanding of sign languages in order to develop better, linguistically grounded models.

1.1 Linguistics and SLMT (how linguistics has informed and can inform SLMT)

Even though sign and spoken languages share fundamental properties in terms of linguistic structure, there are also substantial differences which play out most clearly when multimodality is considered (Vermeerbergen, Leeson and Crasborn, 2007; Janzen and Shaffer, 2023; De Sisto et al., forthcoming, etc.). As MT has been developed based on spoken language characteristics, its techniques are not

immediately applicable to the modality specific challenges that SLs present. In light of this situation, linguistic research is essential in order to inform sign language machine translation (SLMT) work and to assist in developing effective strategies to address such SL modality-specific properties (for an exhaustive description of these properties and how they affect SLMT, see De Sisto et al. forthcoming).

For instance, an SLMT system needs to be able to work with the complexities of the sign language input, rather than text input, which is the usual input for MT targeting spoken languages. In addition to the lack of standardised written representations of SLs, the SLMT system needs to take into account that the sign language input is constructed by multiple (and not necessarily synchronised) streams of information coming from the manual and non-manual articulators (De Sisto et al. forthcoming). We follow Perniss and Özyürek (2015) who note that the body, hands and/or voice is used by signers and speakers when they refer to people, objects, actions and relations between them. Additionally, as Ferrara et al. (2022) note, signed multimodal acts instantiate different semiotic (e.g., symbolic, indexical, depictive) combinations and the ways in which these are manifested varies depending on a range of considerations including, "the availability of different bodily resources, along with the needs and motivation of the people interacting (De Meulder et al., 2019; Ferrara and Hodge, 2018; Kusters et al., 2017)" (Ferrara et al., 2022, p.1). As Ferrara et al. (ibid.) also note, the role of complex socio-historical trajectories of a particular language community is also impactful in this regard.

At present, we do not have adequately robust linguistic descriptions of all of these elements in hand, and, for some items (e.g. simultaneity, depiction), we do not have significant data sets that capture the breadth of use of particular phenomena in contexts that map to the use cases that SignON focused on - our data scarcity issue. Add to this that the technology still is not yet at a point where the richness of what a SL can articulate can be leveraged effectively in SLMT contexts. Narrowing down the focus to what is possible, SignON partners sought to ensure that any form of recognising and encoding what is being signed, must focus on what is being produced by (both) hands, eye gaze, mouth, torso, etc. to support our aim of producing sensible translations. Similarly, in order to generate sign language content via an avatar, descriptions for multiple parameters are necessary.

Additionally, any work on SLMT needs to be based on the knowledge that, even though sign and word can be considered equivalent in terms of grammatical role (Brennan, 1992; Leeson and Saeed, 2012), there is no one-to-one mapping between the two, and they might not be fully comparable to each other.

In particular, while words generally have more or less fixed forms and meanings,¹ signs can be distinguished into two groups: i) established signs, with a more or less pre-defined form and meaning or set of meanings, and ii) signs from the productive lexicon, which do not necessarily have a fixed relationship between form and meaning. This fact means that productive signs cannot be looked-up in a dictionary and that they are strongly context-dependent and may inform the development of neologisms (e.g. Brennan, 1990; Vermeerbergen, 2006; Moïsselle and Leeson, 2022; Moïsselle, in prep.) and cannot be known beforehand. With the current technologies, such signs constitute a great challenge, for recognition, natural language understanding and generation.

Since most of the available data annotations are glosses (De Sisto et al., 2022), considerable studies on SLMT have focused on employing them. The linguistic knowledge and understanding of glosses (as well as on sign languages) has allowed us to identify the limits of such annotations (i.e. they are not able and are not meant to represent the full content of what is being signed) and to develop strategies for using them in a sensible way: for instance to retrieve constituents order from a signed utterance² and extracting lexical sign information from lexicons (De Sisto et al. forthcoming).

Research on the linguistics of SLs commenced in the late 1950s, and today, as a result of a significant move towards building SL corpora in many (but not all) European countries in the 2000s, we see an increase in usage-based description of SLs emerging (Fenlon and Hochgesang, 2022). In SignON we used corpora and resulting research for each of the SignON targeted SLs, and over the course of our project we built upon this research and data. However, much work remains to be done, and across SignON, questions arising around elements of the linguistics of signed languages (e.g. constituent order, depiction, how younger signers sign, etc.) gave rise to focused research to support our ongoing work. In this deliverable, we specifically report on the sign linguistics work the SignON team conducted.

1.2 Deliverable structure

This deliverable is organised as follows. In Section 2.1 we present the linguistic analysis with respect to the different sign languages. The findings from this analysis aid the AMR-based synthesis pipeline by informing the reordering process (see D4.2). Section 2.2 provides an overview of Constituent order in

¹ We acknowledge that producing productive words is possible; however, productive words carry a marked connotation, whereas productive signs do not necessarily.

² However, it needs to be noted that a similar use of glosses cannot fully capture simultaneity.

Sign Language of the Netherlands (NGT). We cover Irish Sign Language (ISL) in Section 2.3, presenting work on depicting signs in Irish Sign Language. Sections 2.4 and 2.5 also provide information on constituent order in British Sign Language (BSL) and Spanish Sign Language³ (LSE) respectively, and the role that knowledge of these phenomena play in generating synthetic SL gloss data for those languages - a technique which is addressed in detail in D3.6 “Second Natural Language Processing Pipeline”, D4.8 “Final Routines for transformation of text from and to InterL”, and other peer-reviewed research by SignON researchers. In Section 3 we report on the ongoing research on SignNets. This work aims to develop semantic networks for signed languages, similar to WordNets that can be used in the retrieval of semantically correct utterances in a translation process.

2. Linguistic analysis of VGT, NGT, ISL, LSE and BSL

2.1 Flemish Sign Language (VGT)

2.1.1 *Constituent Order in Flemish Sign Language*

In the context of MT applications, and within the framework of SignON specifically for WP4 "Transfer and InterLingual Representations" and WP5 "Target message synthesis", there was a need for information on sentence structure, and particularly on constituent order in Flemish Sign Language. Initially, the results of previous research by Vermeerbergen were reviewed (Vermeerbergen, 1996; 1997; 2010; Vermeerbergen et al., 2007). Given the strong suspicion of age-related variation in Flemish Sign Language, especially concerning constituent order, it was decided to complement the existing research with a new study of constituent order in younger signers.⁴

For this purpose, data from the Flemish Sign Language Corpus were analysed (Van Herreweghe et al., 2015). These involved declarative sentences produced by nine 12 to 18-year-old Flemish signers elicited with the Volterra et al. task (Volterra et al., 1984). In this task, eighteen pairs of drawings with only one contrastive element (e.g. ‘a cat is under a chair’ versus ‘a cat is on a chair’) are used to elicit eighteen sentences describing three distinct types of states of affairs: six locative states of affairs, six

³ Lengua de Signos Española

⁴ This study resulted in a very detailed research report in Dutch (Soetemans and Janssens, 2023). There is also a shorter report in Flemish Sign Language to appear on the VGTC website upon completion.

non-reversible states of affairs (only one of the entities in the drawing is likely to be the agent of the action) and six reversible state of affairs (either entity could possibly be the agent).

For the non-locative sentences, the subject (S), object (O) and predicate (V) were identified and their respective position in the sentence was determined. Previous research on constituent order in VGT had shown that whereas lexical verb signs were more likely to appear between the subject and the object, constructions belonging to the productive lexicon (e.g. “classifier constructions”) were often produced at the end of the sentence. Therefore, this study also coded whether the V consists of a lexical verb sign or a “productive predicate”.

For the locative sentences it was decided to focus on the locative relation and use ‘location’ (LC) and ‘located element’ (LE) instead of subject and object. When the locative relation was expressed by a preposition sign (ON, UNDER, etc.) we labelled it LP, other types of expressions of the locative relation (e.g. the use of two classifiers simultaneously to reflect the actual position of two entities relative to each other) were labelled LV.

When signs for different entities were produced simultaneously, this was explicitly coded in the analysis. When the form of a verb sign explicitly referred to one of its arguments this was also indicated. Examples of the latter are the modification of the production of a verb sign in relation to the locus previously established for the object.

Finally, relevant non-manual marking (e.g. topic-marking) and pauses and intonation breaks (often indicating clause boundaries) were also coded.

The analysis of the sentences with non-reversible arguments showed that the most common constituent ordering are SOV (subject - object - verb) and SVOV (subject - verb - object - verb). A number of sentences did not contain a separate sign for the subject or the object. This may have been due to the specific pair of drawings used to elicit the sentence, e.g. when the difference between the drawings was the action and not the subject or the object. However, in these sentences the (productive) predicate contained some form of reference to the subject or object, e.g. by means of an entity classifier handshape as in GIRL “hold-thread” + “cut-thread-with scissors”. Another observation has to do with the predicate in sentences with SVOV order. Whereas in earlier studies this often involved a combination of a

lexical verb sign produced between the S and the O and a productive predicate at the end of the sentence e.g. GIRL EAT CAKE “eat-cake” in these data, there were most often two identical instances of the same productive predicate, i.e. GIRL “eat-cake” CAKE “eat-cake”. With regard to the difference between lexical verb signs and productive predicates, it may be noted that in the sentences with SOV order, the V is usually a productive predicate. In the utterances with SVO (subject - verb - object) order, on the other hand, both lexical verb signs and productive predicates are used.

The analysis of sentences with reversible arguments showed that SVO was the most common constituent order. Here too, there were sentences that did not include a separate sign for the subject or the object. In the case of SVOV again most often we see a combination of two identical instances of the same productive predicate, e.g. GRAND^FATHER “push” GIRL “push”. Overall, the action is most often expressed through the use of a productive predicate, whereas lexical verb signs were relatively scarce. This is the case in all sentences with SOV order but also in the majority of the SVO utterances.

For the locative sentences, the most common constituent orders are:

- location – located element – locative relation not expressed by a preposition sign (LC- LE -LV):

CAR PERSON “person-stand-on-car”

- located element - preposition sign - location (LE-LP-LC): CAT ON CHAIR

- located element – locative relation not expressed by a preposition sign – location (LE-LV-LC):

BOY “person-sits-on-car” CAR

Furthermore, the locative relationship is often expressed by a form of simultaneity, e.g. THERE-IS VASE FLOWER “flowers-next-to-vase” where the non-dominant hand of the two-handed sign VASE is held during the production of the sign FLOWER and actively involved in the production of the classifier predicate “flowers-next-to-vase”.

This study shows that indeed the constituent order used by younger signers differs from the ordering patterns found in the older studies. For example, whereas previous research found that in sentences with reversible arguments signers often used preposition signs or “auxiliary verbs” such as GIVE to indicate the direction of the action, this is rarely the case in this data. Another important observation relates to the position of the V in the case of a productive predicate. Whereas in previous studies productive verb signs always appeared in the final position of the sentence, in this new data productive

predicates also appear between the subject and the object in non-locative sentences and between the located element and the location in locative constructions. This may indicate that these productive predicates are undergoing a lexicalization process.

2.1.2 The impact of video on sign language production and structure

Signed languages are visual-gestural languages, and have to be seen to be understood. They have no (widely used) written form. Therefore, until recently, sign languages were almost exclusively used for face-to-face communication, where the interlocutors are all in the same place at the same time. The influence of a “strictly oral tradition” on the structure of spoken languages is well documented and there is no reason to believe that the same or similar influences do not also exist for signed languages. Johnston (1989 p. 233) gives the following example:

“In particular, both parataxis and topicalization seem to be strongly encouraged by the face to face, unplanned nature of communications in sign language which are always rooted in a shared communicative context between signer and addressee (e.g., Ochs, 1979). Topic-prominence can thus be seen to stem from both (a) conversational face to face discourse patterning of oral cultures and (b) the need to locate in space the agreement point [...].”

Nowadays, sharing space and time is no longer a prerequisite for communicating in a signed language. Signers engage in real-time online video calls (on computers/laptops, tablets and smartphones) and video messages are recorded and sent to a recipient who watches them later. One of the difficulties with using a 3D language through a video-connection is that the language is portrayed in two dimensions (Napier, 2011). This dimensionality reduction is a topic that has been scarcely explored in the international SL linguistics literature.

Clearly, research into the possible impact of signing in front of a video camera on sign language production is important for the development of sign language processing technologies and applications, given the video processing required for automatic sign language recognition.

We conducted a study comparing Flemish Sign Language production in five different settings: 1) face-to-face communication; 2) real-time online communication via laptop; 3) real-time online

communication via smartphone; 4) video-recorded Flemish Sign Language production on a laptop; and 5) video-recorded Flemish Sign Language production on a smartphone.

The main research question of this study is whether and how the use of video to communicate in Flemish Sign Language affects sign language production. Other research questions are:

- How does the use of space differ in the five different settings?
- What about deixis in online language use? For example, is spatial deixis expressed in a more explicit way in 2D as compared to the traditional use of pointing signs in shared 3D space?
- Is there a difference in referent tracking mechanisms?
- Is there more one-handed than two-handed signing in online communication? How does the use of one hand instead of both hands affect the lexicon, syntax and the organisation of the discourse in video-mediated and video-recorded signing?
- Is manual marking used more often than non-manual marking, e.g. in sentence type marking, in online communication?

Each data collection session involved two signers interacting with each other in the different settings. In this initial phase of the project, we limited ourselves to two types of data: short signed narratives based on a picture story and driving/walking directions, both with and without the use of a map.

The video recordings resulting from these data collection sessions are imported into ELAN (Wittenburg et al., 2006) to allow a detailed annotation and analysis of the relevant sequences.

A first analysis⁵ showed that the use of online tools does indeed affect the language production of Flemish Sign Language users, compared to face-to-face communication.

A first important difference is the size and use of the signing space. When communicating via laptop or smartphone, this space is limited by the size of and visibility on the screen.⁶ Obviously, the signing space is smaller when using a smartphone compared to a computer; not only is the screen of a laptop significantly larger, but it is also easier to place the laptop further away from the signer in order to

⁵ These results were presented at SLTAT 2023: Eighth International Workshop on Sign Language Translation and Avatar Technology and published in the proceedings (Soetemans & Vermeerbergen, 2023).

⁶ Julie Hochsegang talks about this as 'emboxed discourse' in the presentation at <https://www.youtube.com/watch?v=tha5sdqrlwE>

“capture” a larger space. The signing space is also higher in front of the body when signing in front of a video than when signing face-to-face. This is because the “standard” signing space is too low to be fully visible on a laptop or a smartphone screen. As a result, certain signs that are performed quite low, are produced with a higher location.

Whereas in face-to-face communication the signer’s torso and head are quite mobile, in part as a result of the hands moving in the signing space, a smaller signing space results in smaller movements of the head and upper body.

If it is not possible to put the smartphone down, the signer has no option but to hold the device with one hand and communicate with only one hand. It follows that in this type of online communication, many two-handed signs are performed with one hand and/or the location parameter of the sign is modified. Furthermore, the use of manual simultaneous constructions is not an option as both hands are not available. We therefore find little or no (list or fragment) buoys in this type of sign language production, although they have been shown to play an important role in structuring the discourse. Future research is needed to analyse what alternatives are possible.

An interesting observation is that the way the same situation is described sometimes differs between face-to-face communication and online communication. A concrete example is the way an intersection is referred to in driving directions. Whereas in the face-to-face communication the traffic lights are depicted, in the video-recorded communication there is reference to a crossroad. This may be related to the choice between established signs and forms from the productive lexicon, with the productive lexicon being more prominent in face-to-face communication.

This is related to the choices made for referent tracking. Online communication makes greater use of nominal reference through established signs and fingerspelling. This may be because this method of referent tracking is less prone to misunderstanding. In face-to-face communication, it is easy to check that the interlocutor is able to identify the intended referent, which is obviously not possible in the case of video-recorded signed language production. In face-to-face communication, we see that the signer produces more squinted eyebrows and head nods, two signals used to check comprehension. The impossibility of checking (in video-recorded messages) whether the other person has understood the message could also explain why there is more repetition of information in online communication, as this

first analysis of the data seems to show. However, there is also evidence that the description of information in online communication is less comprehensive and less detailed than in face-to-face communication. Clearly, more research is needed here.

Also with regard to referent tracking (and the use of the signing space), the possibility to locate referents in the signing space and to refer back to them by pointing to the locus seems to be used less often in online communication. Finally, we also observed an increase in the use of mouthings in online signing, and mouthings seem to be produced more clearly.

Following this exploratory study, two new related studies were set up. A first follow-up study further explores the topic of referent tracking and analyses in detail which forms of referent tracking are used more and which less in the five different settings. Preliminary results indicate that signers show a greater preference for nominal reference tracking mechanisms (e.g. established signs) when (re)introducing referents in online communication compared to (re)introducing referents in offline communication. Furthermore, these preliminary findings show that signers in online communication would make less use of loci and pointing mechanisms to refer back to these referents located previously in the signing space. A more in-depth study is needed to validate these first observations.

A second follow-up study focuses on the lexicon and examines the extent to which the use of video impacts the prevalence of one-handed versus two-handed signs. As an initial benchmark for comparison, we started by analysing 1,000 signs, in citation form, randomly retrieved from the online VGT dictionary. Subsequently, we conducted similar analyses for video-mediated conversations via laptop and smartphone (1,867 signs) and for regular face-to-face interactions in VGT (1,548 signs). An interesting, and somewhat surprising, first observation is that there are significantly less two-handed signs in face-to-face communication, as compared to the dictionary. It seems that two handed signs are often performed with one hand in spontaneous conversations, even if both hands are available. As a result, the distinction between face-to-face communication and video-mediated communication is less pronounced than expected. However, we do find a difference and our preliminary results indicate that signers opt for one-handed signs more frequently when conversing through their laptop or smartphone as compared to face-to-face interactions. Future research must include a more comprehensive analysis of the one-handed versus two-handed ratio, as well as a more in-depth examination of the difference between smartphone- and laptop-mediated communication. Further analysis will also show whether, when

switching from two-handed to one-handed signs, Flemish signers are more likely to perform a two-handed sign with one hand or to select a one-handed synonym.

For both follow-up studies a publication is in preparation.

2.2 Sign Language of the Netherlands (NGT)

In order to define reordering rules to be used as part of the Text-to-Gloss translation task, we have consulted sign language linguistic studies concerning the order of constituents in Sign Language of the Netherlands (NGT). It has been claimed that the predominant basic constituent order in declarative affirmative clauses in NGT is subject - object - verb (SOV) (Coerts, 1994; Brunelli, 2011; Oomen and Pfau, 2017). However, both subject - object - verb (SOV) and subject - verb - object (SVO) orders are attested in the language (Van Gijn, 2004; Klomp 2021). Because of simultaneity, V and O can be articulated at the same time (for example when O is expressed with a classifier); this makes it hard to define whether the structure of the utterance is SOV or SVO (Leeson and Saaed, 2012). Negation generally precedes the verb phrase, however, cases in which this follows it are attested, although less common (Oomen and Pfau, 2017). In declaratives, time and space generally precede the basic constituents. WH- elements with a role of subject generally occur sentence/message-finally, but can also be placed in the subject position, while WH-objects can appear either in object position or either at the beginning or at the end (Klomp, 2021). Topicalisation and focalisation can affect constituent order: focused constituents might appear clause-initially (Klomp, 2021). Additionally, it has been observed that in coordination, the second conjunct can show fronting of a constituent in order to create contrastive focus interpretation, as in “Mary is going to school, and to college, Vivian (goes)” (Legeland et al., 2018, p. 56). Another property which complicates constituent orders is the possibility of doubling some constituents.

2.3 Irish Sign Language (ISL)

2.3.1 Neologisms in Irish Sign Language - Depiction as a Driver of Change

Earlier, we referenced the multimodal resources that sign languages draw upon. Building on this, we can say that sign languages can visually represent semantic components through a linguistic mechanism that is labelled as ‘depiction’ (Liddell, 2003; Dudis, 2004). In employing depiction, signers ‘provide information about what an entity or event is like, what it looks like, or even what it acts like’ (Thumann, 2013, p. 316). This is not unique to signers: speakers also make use of depiction in taking on the role of

other people, quoting their speech or imitating their actions. Depiction can have a significant semantic role in a sentence (Ferrara & Johnson, 2014; Hodge & Johnson, 2014; Lu & Goldin-Meadow, 2018) and is a ubiquitous phenomenon in the production of sign languages (Metzger, 1995; Quinto-Pozos, 2007; Cormier et al, 2015). While some elements of this have been described for ISL, with particular attention on ‘the productive lexicon’ (Leeson & Grehan, 2004; Leeson & Saeed, 2012; Matthews, 1996; O’Baoill & Matthews, 2000), in the work summarised below, researchers at Trinity College Dublin have furthered the analysis using methods from cognitive (sign) linguistic research to better support our understanding of these phenomena and to inform SLMT work that will go beyond the life of the SignON project.

For this study of depiction in ISL, we analysed data from several recently developed domain-specific glossaries including Science Technology Engineering Math¹ (STEM), Covid-19², the political domain⁷, and Sexual, Domestic and Gender Based Violence (SDGBV) related vocabulary⁸. Analysis to date suggests that a deliberate focus on iconicity - specifically elements of depiction - appears to be a primary linguistic driver for these new terminologies. Moisselle (in prep) provides a novel approach to defining the depiction strategies adopted by including consideration of gesture studies approaches in combination with sign language specific considerations. Building on Moisselle and Leeson (2022), this work makes reference to prospective empirical data collection with stakeholders involved in the development of these glossaries, which are intended to facilitate an understanding of the linguistic ideologies that help drive contemporary community decision making around new vocabulary.

| Dataset | | | |
|-------------------------|----------|--|----------------------|
| Theme | Size | Developed by | Hosted by |
| Glossary of SDGBV Terms | 80 items | Centre for Deaf Studies (including a phased process with deaf interpreting students), Irish Deaf Society, National Deaf Women of Ireland, Council of Irish Sign Language Interpreters. | Justisigns 2 Project |

7

<https://www.oireachtas.ie/en/how-parliament-is-run/houses-of-the-oireachtas-service/equality-diversity-and-inclusion/irish-sign-language-in-the-oireachtas/isl-glossary-background/>

⁸ <https://justisigns2.com/outputs> (Finalised ISL glossary to be added here shortly).

| | | | |
|---|-----------|---|--------------------------|
| COVID-19 glossary | 10 items | Irish Deaf Society, the Council of Irish Sign Language Interpreters, and the Centre for Deaf Studies. | Irish Deaf Society |
| STEM glossary | 818 items | Dublin City University (DCU) and Science Foundation Ireland (SFI) | Dublin City University |
| Houses of the Oireachtas parliamentary glossary | 83 items | Oireachtas ISL Team and the Centre for Deaf Studies. | Houses of the Oireachtas |

The key goal of this study is to examine how neologisms form in Irish Sign Language. We have identified that depiction is playing a significant role in this regard in the data sets of neologisms that we are examining. Through this work, we are documenting the patterns that operate across disparate domains (STEM, politics, gender based violence/legal terms) which helps us to plan forward in understanding the ways in which SLMT may handle new terms in sign languages. We have drawn on the canon of research from both sign linguistics and gesture studies to develop a taxonomy through which to define depiction strategies. The linguistic analysis follows two distinct phases, the first of which entails a feature analysis of vocabulary to contextualise the incidence rate of depiction relative to other linguistic features that are present in the data. This phase also provides insight and commentary into the linguistic motivators of neologisms in ISL more broadly. The features examined are:

| | | |
|--------------------------|-----------------------------------|--------------------|
| Initialisation | Depiction | Arbitrary |
| Mouthing | Metaphor | Metonymy |
| Body Partitioning | Simultaneous Constructions | Compounding |

The second phase of work entails an analysis of depiction. We draw on the work of English (2022) who builds on a significant body of Gesture Studies research (e.g. Müller, 1998 Mason-Carro, Groudbeek and Kramer, 2016; 2017; and Hwang et al., 2017). The key depiction strategies considered (traditionally for hearing gesturers) in this regard are defined and described by English (2022, p.77):

| | |
|------------------|------------------------|
| Handling | Enactment |
| Portrayal | Molding |
| Drawing | Personification |
| Placing | Other |

Taking a sample set for illustration, we can show that depiction, metaphor, mouthing and metonymy are highly prevalent components in the Sexual, Domestic and Gender Based Violence glossary and 84% of signs in the DSGBV glossary are depicting, reflecting intentional decisions made by the creators of the corpus, which were confirmed by multiple rounds of stakeholder engagement. This tells us that contemporary ISL signers have a strong preference for depicting signs rather than, for example, initialised signs or signs seen as completely arbitrary in nature.

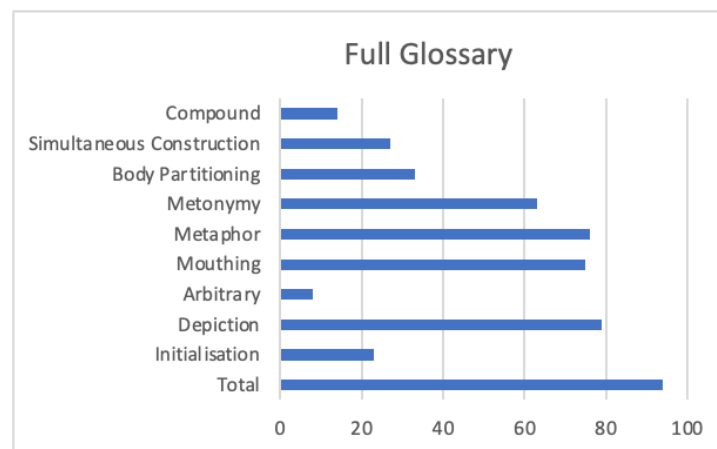


Figure 1: Results of the Feature Analysis of the DSGBV Glossary

With respect to the analysis of depiction strategies, the integrated gesture studies taxonomy in combination with sign language specific considerations has proved to be a fruitful tool for analysing and categorising how depiction presents in these glossaries. The fact that a gesture studies taxonomy is so applicable in analysing sign language strategies serves as a compelling argument against the formalist notion that there is a clear dichotomy between (sign) language and gesture. The following aspects are noteworthy: (1) thus far, depiction has co-occurred with embodiment 100% of the time in the neologisms examined; (2) thus far we have not observed instances of ‘drawing’ or ‘other’ (presenting,

beats, pointing) in the glossaries examined. Instead, enactment is the most common depiction strategy (50%) in this glossary.

A related goal, and one that maps to SignON’s commitment to co-creation and end-user engagement, is via focus groups, to document and analyse the motivations (linguistic/sociolinguistic) and key concerns of those who led work on the creation of these new glossaries (predominantly members of the Deaf community) and the wider deaf community who informed the development of the neologisms in the data sets we analyse. Aligned to this, discussion has also stimulated conversations around macro-level equality, diversity, and inclusion related matters (e.g., following commencement of the Irish Sign Language Act, 2017).

While this work, still progressing, has had limited immediate impact on the SignON app, it brings important and more nuanced understanding of what has traditionally been called ‘the productive lexicon’ and shows how elements from productive signing informs new signs, which are now being used as part of the established lexicon. Better understanding the processes, drivers, features and constraints that operate in this regard will help us predict what kinds of signs Deaf communities are open to, which, in turn, may help in bridging the gap that SLMT faces around incorporating the productive lexicon.

2.3.2 Gerunds in Irish Sign Language

In this section, we focus on work that TU Dublin has led, investigating gerund constructions in Irish Sign Language (ISL). This research is motivated by the challenging nature of those constructions in linguistic terms and the lack of research with regard to this linguistic phenomenon across many sign languages, including Irish Sign Language. In addition, gerunds will inform computational modelling and provide a significant addition to sign language literature.

From a linguistic perspective, a gerund is a form of verb that functions as a noun. In English, they are represented using the suffix *-ing* at the end of verbs. An example of an English language gerund is *destroying* in the sentence “Destroying the files was a serious mistake.” (Huddleston and Pullum, 2016, p. 81).

In English, for instance, the importance of gerunds comes from their variety of uses, essentially in nominalisation in addition to many other uses, such as subjects, extraposed subjects, subject

complements, direct objects, prepositional objects, or complements of prepositions (Biber et al., 1999, pp. 201–202).

We investigate the existence in sign languages of constructions similar or equivalent in functionality to gerunds in spoken language, in particular, English.

We focus on aspect and aspectual marking in ISL, as both gerund constructions and progressive aspect share the use of the same construction type i.e. the verb. In addition, the internal structure of both gerunds and progressive aspect is similar. Leeson and Saeed (2012: 103) posit that aspectual marking in ISL is associated with modifications to the movement parameter, similar to ASL (Klima and Bellugi (1979:24), with reduplication being of particular significance (ibid.). Based on existing literature, reduplication of the sign seems to be significant in the marking of progressive aspect. In NGT, reduplication of the verb is the main aspectual marker for continuous or progressive aspect (Pfau et al., 2012) (Oomen, 2016). The case is similar in LSE (López et al., 2020) and in BSL (Margaret Deuchar, 1984) (Sutton-Spence & Woll, 2007).

Leeson and Saeed (2012) further posit that the situation type of the verb, whether static or dynamic conveys different meaning, with static situation type corresponding to no change for a period of time and dynamic corresponding to change. In ISL, durational verb types correspond to events continuing through time, whereas punctual verbs correspond to events involving very little time.

Within this research, we use the Sign of Ireland (SOI) corpus. The SOI corpus consists of data that is collected from 40 participants (males and females) from many parts of the Republic of Ireland, including Dublin, Cork, Galway, Waterford, and Wexford. Participants shared two forms of stories: frog story (used in cross-linguistic studies), and a personal story from the participant's life (Leeson et al., 2006).

ELAN software was used in this research to facilitate analysing the SOI corpus. ELAN is a software application that facilitates creating annotations for video data. It was developed by the Max Planck Institute for Psycholinguistics, The Language Archive, Nijmegen, The Netherlands (Sloetjes and Wittenburg, 2008). The SOI corpus is annotated using lexical glossing, which is a method of expressing the meaning of signs using English text. Glosses are written in block capitals and used to reflect the meaning of a sign or multiple signs in a spoken language (Vermeerbergen, 2006). A manual approach is used for the analysis of the data. We used 43 videos that are fully annotated to carry out our

investigation. Gerund constructions were observed in 23 videos. We focused on the occurrence of reduplication of verb signs within the SOI corpus personal stories.

It is important to note that while the reduplication of a verb sign in ISL may correspond to verb inflection in spoken languages (Leeson and Saeed, 2012, p. 104) the repetition of a sign may refer to pluralisation as seen in Example 2.1 where the sign BEE is reduplicated to reflect the meaning of BEES (bee plural).

Example 2.1

LOT-OF BEE++ IN DRINK

“Lots of bees in (my) drink.”

SOI Corpus Mary (30) personal stories (Cork)

In example 2.2, the sign SWEAT is reduplicated to manifest a gerund “sweating”, as the sentence context indicates that the main verb is STOP and the use of the inflected sign SWEAT is nominal.

Example 2.2

SWEAT ++ NEVER STOP INDEX+c CL-V+LOOK-AT SWEAT BECAUSE WEATHER WAS HOT

“I never stopped sweating because the weather was hot.”

SOI Corpus Mary (30) personal stories (Cork)

In Example 2.3, the sign WAVE is repeated three times, and the 5-classifier is performed twice using the non-dominant hand to indicate the meaning of “waving”.

Example 2.3

CL-ISL-L BENT +me CL-ISL-V-LOOK SEE INDEX+c COUSIN FAR-AWAY WAVE+++

“I was looking to see my cousin far away waving.”

SOI Corpus Linda (40) personal stories (Waterford)

While this research is still a work in progress, initial findings indicate the existence of constructions similar or equivalent to gerund constructions in spoken language. Future work will investigate these constructions further, including the different forms that these constructions may take. This research will serve as an invaluable resource in the computational modelling and processing of signed language, providing a more comprehensive understanding of how this challenging linguistic phenomenon manifests itself.

2.4 British Sign Language

2.4.1 Constituent order and topic-comment structure in BSL

Again, constituent order is an important feature of this SL with regards to the SignON project's translation task and its reliance on SL glosses. However, BSL's sign order is also particularly interesting from a typological perspective. The predominant basic order of constituents in a declarative phrase is said to be object - subject - verb (OSV) (Sutton-Spence and Woll, 2007) - an order which is vanishingly rare amongst the world's languages (Dryer, 2013). However, as described for NGT, and as is the case in many SLs, topicalisation plays an important role in shaping the order of BSL constituents. BSL employs the fronting of constituents which are new or pertinent to the discourse. A simple example of this basic order is shown in (Example 2.5), followed by variations of this phrase which topicalise a particular element.

Example 2.5.

BOY HORSE DON'T-LIKE

boy horse dislike

"The horse doesn't like the boy" (Canonical OSV order)

HORSE BOY DON'T-LIKE

horse boy dislike

"As for the horse, it doesn't like the boy" (Topicalised Subject, SOV order)

DON'T-LIKE BOY HORSE

dislike boy horse

"As for liking the boy, the horse doesn't" (Topicalised Verb, VOS order)

Example 2.6.

YESTERDAY GARDEN PT:POSS.2SG TREE CAT BLACK CLIMB WHAT-FOR

yesterday garden IX.2SG.GEN tree cat black climb why

"Why was the black cat climbing the tree in your garden yesterday?"

As is attested in other SLs, often a spatio-temporal framework is set up before the referents within it are introduced and commented upon (c.f. Sutton-Spence and Woll, 2007:59). This means it would be more accurate to state that its order is ‘Time - location - object - subject - verb - question’⁹. Table 1 shows and labels example BSL phrase (Example 2.6) which incorporates all these constituents.

Table 1: Canonical order of constituents in BSL for the sentence: “Why was the black cat climbing the tree in your garden yesterday?”

| Role/Constituent | Example |
|------------------|----------------|
| Time | yesterday |
| Location | in your garden |
| Object | the tree |
| Subject | the black cat |
| Verb | climbing |
| Question | why |

As described in D3.6 “Second Natural Language Processing pipeline”, we used the functionality of our NLP pipeline as well as a model which labels semantic roles in English in order to generate synthetic BSL glosses from monolingual English data. It was possible to extract elements of a given sentence which could be described as the topic, question words, spatio-temporal elements, as well as the rest of the argument structure of the sentence. These were then reordered into the order shown in Table 1 to create synthetic BSL glosses for use in the pretraining of text-to-gloss SLMT models. This process, and its performance, is described in D4.8 “Final Routines for transformation of text from and to InterL”.

2.5 Spanish Sign Language

2.5.1 Synthetic LSE glosses based on linguistic features visible in LSE glosses

During SignON, we conducted research into creating text-to-gloss and gloss-to-text SLMT models between LSE and Spanish. These models are first pre-trained on parallel Spanish/synthetic LSE gloss data,

⁹ <https://garethejones.wordpress.com/2008/03/21/bsl-word-ordering/> (also where the Example 2.6 in Table 1 is taken from)

before being fine-tuned on the small amount of available, real parallel data between these two languages (described in detail in Chiruzzo et al., 2022; McGill et al., 2023).

The synthetic glosses were created by means of a rule-based approach based on our knowledge of the grammar and unique features of LSE (e.g. Rodríguez-González, 1992; Herrero-Blanco, 2009). They were also chosen because they were reflected clearly in a text form - glosses - and appeared in the target datasets on which we were testing these translation models. Therefore, the following (potentially disparate) features of LSE are listed to show some examples of the language.

First among which is the syntax of negatives. The negative particle always occurs after a verb or noun phrase, and for certain verbs - particularly those which are more frequent or are auxiliary verbs - is lexicalised as a new sign (Rodríguez-González, 1992). Example 2.7 shows an example of each in gloss form from the iSignos corpus¹⁰.

Example 2.7

EMPEZAR INTEGRACIÓN SIGNAR2 NADA

start integration sign nothing

“[I] started integrating but I didn’t know any sign language”

INDX.PRO:1sg ENTENDER NO

IX.NOM.1SG understand not

“I don’t understand”

COMUNICAR PADRE^MADRE HABER-NO

communication parents have.NEG

“[I] didn’t have communication [abilities with my] parents”

Another feature of LSE is that signs can be inflected by means of numeral incorporation. Signs for numbers up to ten¹¹ may often be incorporated into other signs such as for expressing a duration “MES-TRES (three months)” or an amount of people “INCLUIR-CINCO (to include five people)”.

¹⁰ <http://isignos.uvigo.es/en/>

¹¹ The maximum number of fingers on both hands

For comparison with the other SLs mentioned in this deliverable, it has been noted that the canonical constituent order of LSE is Subject-Object-Verb (Herrero-Blanco, 2009), but topicalisation has a strong effect on the order of constituents in a phrase in context (Morales-Lopez, 2023). Noun phrases are also said to have a specific order of components if they are included: noun, demonstrative, possessive, numeral, indefinite (Herrero-Blanco et al., 2009). Finally, as with other SLs, LSE uses reduplication to mark plurals and for emphasis (San-Segundo et al., 2008).

3. SignNets

In parallel to the best efforts of our consortium in producing glosses via rule-based and more complex symbolic representations, the technical partners of CCL-KU Leuven and VGTC have also started research on a linguistic resource on sign languages, called a SignNet. We recognise that within the scope of SignON this SignNet has not come to fruition. However, as we envision it, it could be used for looking up potential meanings of any sign. It is currently not part of our pipeline but serves as a foundation in linguistic research, analogous to WordNets that have been created for spoken languages, to ensure that sign languages are equally represented in terms of their linguistic tools and descriptive frameworks.

A SignNet is based on the principle that signs express a concept or meaning, and we want to link these concepts between SLs and also with existing spoken languages, similar to how Open Multilingual WordNet (OMW) defines semantic fields (synsets) which can be linked across many languages (Schuurman et al., 2003a; cf also Bigeard et al. 2022).

We faced a number of challenges when working on this research. The concept expressed by (a series of synonymous) lexical signs may be broader than that expressed by a word in spoken language. Those concepts are more fine-grained. An example is the sign FISH in VGT which is used for many different types of fish (salmon, cod, halibut, ray, etc.) and the VGT sign used to refer to several insects that sting such as a bee, a wasp and a mosquito. Where more fine-grained differences are important, fingerspelling may be used to contextualise a sign (Ferarra et al, 2022) and/or mouthing is used with the more generic sign to offer specification (e.g. INSECT co-occurs with the mouthing for “wasp”). In some cases, there is one superordinate term in the spoken language, e.g. the Dutch “bestek” (cutlery) whereas there is not one sign referring to the broad concept and instead, subordinate exemplars are used (e.g. fork, knife,

spoon). This is a process that is reported across many sign languages (e.g. ISL, BSL, ASL, VGT, NGT, etc.). In such cases we are also making use of hyponym and hypernym relations to link concepts expressed by the words and signs under consideration. The same sign may also have different, related meanings, e.g. the same VGT sign is used for the concepts “farm”, “farmer”, “farming” etc. (Schoorman et al, 2003b).

In some cases the surrounding spoken language lacks a single word to express a specific concept. An example is the sign showing the type of applause used in the Deaf community. While this sign is found in many SLs, there are no specific words for this concept in spoken languages. In many signed languages there are different signs for “chatting” that encode the modality of discourse the chatting occurs in, e.g. a sign for CHATTING (in a spoken language) versus CHATTING (in a sign language).

Clearly, there is no one-to-one relationship between the signs from a signed language and the words from a spoken language. This is also the case for words from two different spoken languages (e.g. “doen” and “maken” in Dutch versus “faire” in French) but the differences are probably greater when a sign language and a spoken language are involved. We may note here that the established lexicon of VGT appears to be remarkably smaller than that of spoken languages (Vermeerbergen, 2006). The same observation has been made for other signed languages (e.g. Johnston & Schembri, 1999 for Australian Sign Language.)

In SL dictionaries and/or Signbanks most often there is no information documented that relates to Part of Speech. We may note here that there are several signs where the same form is used both as a noun and a verb, e.g. the sign FIETS in VGT and NGT which means both bicycle and to ride a bicycle, depending on the context. However, we note that movement can play an important role in differentiating between verb-noun pairs (Klima and Bellugi, 1979, Brennan, 1992; Leeson and Saeed 2012).

In many sign languages, including VGT, there is considerable regional variation in the lexicon. This also means that while in one Flemish region there may be a single sign with a more general meaning (e.g. in one region there is one single sign for various insects that sting), in another there are different signs with more specific meanings (e.g. MOSQUITO and BEE).

We can link our SL glosses with several OMW-identifiers because the OMW synsets are very fine-grained and because several parts of speech can be involved. For instance, in VGT the concept KOKEN (to cook)

can refer to the verb, but also to the nouns ‘keuken’ (kitchen) and ‘kok’ (cook). In OMW at least three synsets are involved. Ideally, at a later stage, umbrella identifiers can be added covering the whole concept expressed by signs, not just the separate components (as they occur in spoken language). Also in this case, we are using temporary dummy identifiers that could be transformed into an OMW-one at a later stage.

Within SignON, our work on SignNets has focused on VGT and to a lesser extent NGT. In both cases the surrounding spoken language is Dutch. So Open Dutch WordNet would be the first wordnet to use when looking for the OMW identifier. In cases where OMW does not contain the concept we need (e.g., ‘applause by deaf people’) we develop that entry ourselves with a temporary dummy identifier, cf above. The core idea therefore is to also introduce new identifiers for concepts that are not already present in OMW.

Signs in sign languages may undergo a shift in meaning, broadening the meaning of the original sign. For example, DRIVING is an iconic sign that shows the action of steering the wheel of a car, it is also used to refer to the thing you need to do this action (i.e. car or vehicle) as well as the person performing the action (i.e. driver). It is also the sign for STEERING-WHEEL. It is not always clear which meaning came first and how the meaning shifted. Also, it seems that, due to the extended use of smart phones for visual remote communication, signers produce two-handed signs more often with one hand or select one-handed alternatives (Soetemans and Vermeerbergen, 2023).

We have described a number of discrepancies between lexico-semantic units of spoken and signed languages, which inevitably also lead to translation difficulties. Yet, it is our belief that, certainly as long as there are no large parallel corpora (SL-SpL) available, SignNets will be useful to find the best signs via the interlingual index, when translating lexical units from spoken to signed languages. When translating from signed to spoken language, the resulting text will be much more acceptable when useful words can be chosen from a larger palette. In our approach, we are first concentrating on complex cases, in order to avoid developing a system that will need to be redeveloped at a later stage because it is not flexible enough. And we also want to avoid developing a semi-spoken-language system in which signs can be considered a kind of illustration in addition to or on top of spoken languages.

4. Conclusion

It is important to note that linguistic research in the SignON project was at the service of technical developments. Thus, the topics of linguistic research activities were driven by the needs of the technical partners. For example, after the start of the project, it became clear that there was a great need for information on constituent order. This led to an inventory of existing knowledge for different sign languages and additional research. With regard to the lexicon, there was a need for a better understanding of the productive lexicon to inform the development of the RRG + Sign_A lexicon architecture, in order to allow the development of a lexicon architecture that was sufficiently robust in nature to accommodate both the established and productive lexicon for each sign language analysed.

Regardless of the progress on the linguistic analysis at some point of the project (in year 2), it was clear that the lack of automatic methods to generate Sign_A is a hurdle that needed to be overcome. So even while Sign_A is theoretically relevant, we could not generate it automatically leading to the decision to switch from Sign_A to another approach. This decision made the research on the productive lexicon somewhat less urgent. But it is clear that this knowledge is absolutely necessary for future work on SLR and SLMT, e.g. even relying on the automated generation of AMR, AMR concepts had to be (re)ordered correctly to inform the avatar synthesis component.

Some themes did not present themselves until later in the project. An example is the topic of the impact of video on sign language production. This also means that the results of related research are still limited and further research is absolutely necessary.

As the technological research progressed, specific questions about the linguistics of sign languages presented themselves. To address these, regular meetings were organised (online or face-to-face) to share linguistic expertise. In some cases, specific questions led to small research activities, e.g. on complex sentence structures in VGT and the use of ID glosses. Although these rarely resulted in presentations or publications due to the limited scope of the research and/or lack of time, it is important to mention these activities. Future projects should provide for this kind of engagement and exchange as it enriched the project, supported team-building and also highlighted the gaps in our collective knowledge.

During the course of the SignON project it became clear that there is a great need for additional research on sign languages. For a number of European sign languages there is still a lack of the descriptions of even basic structures and processes (e.g. pluralisation), or we have only a fairly general understanding of a particular mechanism and detailed information is lacking. If we take the example of pluralisation: for a number of sign languages the morphological processes of pluralisation have been described, but there is no concrete information about which sign can take which plural forms and which cannot. The current limitations impact on how technical partners can access reliable scientific descriptions of sign languages fundamental to their work. This needs to be addressed to support future SLMT projects like SignON. This is also a key reason why SLMT projects must ensure that they have sign linguists on their teams.

For further (extensive) research, we stress that machine-readable corpora are indispensable (Johnston, 2008; Fenlon and Hochseingang, 2022), but there are several problems here:

1. securing funding for corpus building and annotation - this is essential to help address the data scarcity issue that SignON has raised across the life of the project and in our outputs (e.g. the NGT HoReCo corpus (De Sisto et al., 2023)) but addressing this requires commitment from funders at European and national and regional levels;
2. manually annotating sign language data is extremely time-consuming. This means that most existing sign language corpora are still only partially annotated. It is hoped that advances in ASR and SLMT will speed up the annotation process. This again highlights the interdependence of sign language research and sign language technology.

References

Biber, D., Johansson, S., Leech, G., Conrad, S., & Finegan, E. (1999). Longman Grammar of Spoken and Written English. Pearson Education Limited.

Bigeard, S., Schulder, M., Kopf, M., Hanke, T., Vasilaki, K., Vacalopoulou, A., Goulas, T., Dimou, A.-L., Fotinea, S.-E., and Efthimiou, E. (2022). Introducing Sign Languages to a Multilingual Wordnet: Bootstrapping Corpora and Lexical Resources of Greek Sign Language and German Sign Language. In Proceedings of the LREC2022 10th Workshop on the Representation and Processing of Sign Languages: Multilingual Sign Language Resources, pages 9–15, Marseille, France. European Language Resources Association (ELRA). URL: <https://www.sign-lang.uni-hamburg.de/lrec/pub/22036.html>

Brennan, M. (1992). The visual world of BSL: An introduction. In Brien, D., editor, Dictionary of British Sign Language/English, pages 1–133. London: Faber and Faber.

Brunelli, Michele (2011). Antisymmetry and sign languages: A comparison between NGT and LIS. Amsterdam: University of Amsterdam doctoral dissertation

Chiruzzo, L., McGill, E., Gómez, S. E., & Saggion, H. (2022) Translating spanish into spanish sign language: Combining rules and data-driven approaches. In Proceedings of the Fifth Workshop on Technologies for Machine Translation of Low-Resource Languages (LoResMT 2022), pp. 75-83.

Coerts, Jane (1994). Constituent order in Sign Language of the Netherlands. In Brennan, M. & G.H. Turner (eds.), Word-order issues in sign language. Durham: ISLA, 47-70.

Declerck, T., Bigeard, S., Khan, F., Murtagh, I., Olsen, S., Rosner, M., Schuurman, I., Tchechmedjiev, A., and Way, A. (2023). A Linked Data Approach for linking and aligning Sign Language and Spoken Language Data. In Proceedings of the Second International Workshop on Automatic Translation for Signed and Spoken Languages, pages 11–21, Tampere, Finland. European Association for Machine Translation.

De Meulder, Maartje, Annelies Kusters, Erin Moriarty & Joseph Murray (2019). Describe, don't prescribe. The practice and politics of translanguaging in the context of deaf signers. *Journal of Multilingual and Multicultural Development* 40(10). 892–906.

De Sisto Mirella, Vincent Vandeghinste, Santiago Egea Gómez, Mathieu De Coster, Dimitar Shterionov and Horacio Saggion (2022). Challenges with Sign Language Datasets for Sign Language Recognition and Translation. *Proceedings of the Language Resources and Evaluation Conference 2022 (LREC2022)*. European Language Resources Association. Marseille, France

De Sisto, M., Vandeghinste, V., & Shterionov, D. (2023, June). A New English-Dutch-NGT Corpus for the Hospitality Domain. In *Proceedings of the Second International Workshop on Automatic Translation for Signed and Spoken Languages* (pp. 34-37).

De Sisto Mirella, Irene Murtagh and Myriam Vermeerbergen. In press. Sign Languages and Machine Translation: Challenges and Opportunities. In Lorraine Leeson, Andy Way and Dimitar Shterionov (Eds.), *Sign Language Machine Translation. Machine Translation: Technologies and Applications* Springer.

Dryer, M. S. (2013) Order of Subject, Object and Verb (v2020.3) In: Dryer, M. S. and Haspelmath, M. (Eds.) *World Atlas of Linguistic Structures*. Online: Zenodo.

Dudis, Paul (2004). Body partitioning and real-space blends. *Cognitive Linguistics* 15 (2), 223-238.

Fenlon, J. and Hochseggang, J. (eds.) (2022) *Signed Language Corpora*. Washington DC: Gallaudet University Press.

Ferrara, L., & Johnston, T. (2014). Elaborating who's what: A study of constructed action and clause structure in Auslan (Australian Sign Language). *Australian journal of linguistics*, 34(2), 193-215.

Ferrara, Lindsay, Benjamin Anible, Gabrielle Hodge, Tommi Jantunen, Lorraine Leeson, Johanna Mesch and Anna-Lena Nilsson (2022). A cross-linguistic comparison of reference across five signed languages. *Linguistic Typology* .<https://doi.org/10.1515/lingty-2021-0057>

Ferrara, Lindsay & Gabrielle Hodge (2018). Language as description, indication, and depiction. *Frontiers in Psychology* 9. 716.

Gijn, Ingeborg van (2004). The quest for syntactic dependency. Sentential complementation in Sign Language of the Netherlands. Amsterdam: University of Amsterdam doctoral dissertation

Herrero-Blanco, Á. (2009) Gramática Didáctica de la Lengua de Signos Española. SM, Madrid

Huddleston, R., & Pullum, G. K. (2016). The Cambridge Grammar of the English Language (9th ed.). Cambridge University Press.

Janzen, T. and Shaffer, B. (eds.) Signed Language and Gesture Research in Cognitive Linguistics. De Gruyter.

Johnston, T. (1989) Auslan: The sign language of the Australian deaf community. Doctoral dissertation, University of Sydney, Sydney.

Johnston, Trevor (2008), *Corpus Linguistics and Signed Languages: No Lemmata, No Corpus*. Paper Presented at the 3rd Workshop on the Representation and Processing of Sign Languages (LREC), Marrakech, Morocco, May 2008 [<http://www.lrec-conf.org/proceedings/lrec2008/>, 82–87]

Johnston, Trevor & Schembri, A. 1999. On Defining Lexeme in a Sign Language. *Sign Language & Linguistics*. 2/2, 115-185.

Klima, E. and Bellugi, U (1979). The signs of language. Harvard University Press.

Klomp, Ulrika (2021). A descriptive grammar of Sign Language of the Netherlands. PhD dissertation. LOT, Amsterdam.

Kusters, Annelies, Massimiliano Spotti, Ruth Swanwick & Elina Tapio (2017). Beyond languages, beyond modalities: Transforming the study of semiotic repertoires. *International Journal of Multilingualism* 14. 219–232.

Leeson, Lorraine and Saeed, John. (2012). Word order. *Sign Language: An International Handbook*, edited by Roland Pfau, Markus Steinbach and Bencie Woll, Berlin, Boston: De Gruyter Mouton, pp. 245-265.

Leeson, L. and Saeed, J.I. (2012) *Irish Sign Language*. Edinburgh: Edinburgh University Press.

Leeson, L., Saeed, J., Byrne-Dunne, D., Macduff, A., & Leonard, C. (2006). Moving Heads and Moving Hands: Developing a Digital Corpus of Irish Sign Language. The 'Signs of Ireland' Corpus Development Project. Proceedings of Information Technology and Telecommunications Conference, Carlow, Ireland.

Legeland, Iris; Hartmann, Katharina; Pfau, Roland (2018). Word order asymmetries in NGT coordination: The impact of Information Structure». FEAST. Formal and Experimental Advances in Sign language Theory, Vol. 2, p. 56-67.

Liddell, S. (2003) Grammar, gesture, and meaning in American sign language. Cambridge: Cambridge University Press.

López, E. M. M. L., Casanova, C. P., Varela, C. R., Díaz, E. B., García, N. B., Rodríguez, C. F., Novás, B. M., & Vázquez, G. P. (2020). Aspectos gramaticales de la lengua de signos española (Grammatical aspects of Spanish sign language).

Margaret Deuchar. (1984). British Sign Language.

McGill, E., Chiruzzo, L., Egea-Gómez, S., and Saggion, H. (2023) Part-of-Speech tagging Spanish Sign Language data and its applications in Sign Language machine translation. In: Proceedings of the Second Workshop on Resources and Representations for Under-Resourced Languages and Domains (RESOURCEFUL-2023), pp. 70-76

Metzger, M. (1995). Constructed dialogue and constructed action in American Sign Language. *Sociolinguistics in deaf communities*, 1, 255-271.

Moiselle, R. and Leeson, L. (2022) Language Planning in Action: Depiction as a Driver of New Terminology in Irish Sign Language. LREC 2022.

Morales López, E., Reigosa Varela, C., & Bobillo García, N. (2023). El orden de los constituyentes en los enunciados declarativos de la lengua de signos española (LSE). Una perspectiva funcionalista. *Anuari De Filologia. Estudis De Lingüística*, 2, 77–121. <https://doi.org/10.1344/AFEL2012.2.6>

Napier, J. (2011) “Here or there? An assessment of video remote signed language interpreter- mediated interaction in court.” In: S. Braun and J.L.Taylor (eds.), *Videoconference and remote interpreting in criminal proceedings*, University of Surrey, Guildford, pp. 145 – 185.]

Oomen, M. (2016). The marking of two aspectual distinctions in Sign Language of the Netherlands (NGT). *Linguistics in Amsterdam*.

Oomen, Marloes & Roland Pfau (2017). Signing NOT (or not): A typological perspective on standard negation in Sign Language of the Netherlands. *Linguistic Typology* 21(1). 1-51.

Perniss, Pamela & Aslı Özyürek (2015). Visible cohesion: A comparison of reference tracking in sign, speech, and co-speech gesture. *Topics in Cognitive Science* 7. 36–60.

Pfau, R., Steinbach, M., & Woll, B. (Eds.). (2012). *Sign Language: An International Handbook* (1st ed.). De Gruyter Mouton.

Quinto-Pozos, D. (2007). Can constructed action be considered obligatory?. *Lingua*, 117(7), 1285-1314.

Rodríguez-González, M. A. (1992) *Lenguaje de signos*. Barcelona, Confederación Nacional de Sordos de España and Fundación ONCE.

San-Segundo, R., Barra, R., Córdoba, R., D’Haro, L. F., Fernández, F., Ferreiros, J., Lucas, J. M., Macías-Guarasa, J., Montero, J. M., and Pardo, J. M. (2008) Speech to sign language translation system for Spanish. *Speech Communication*, 50(11), 1009-1020

Schuurman, I., Declerck, T., Brosens, C., Janssens, M. Vandeghinste, V. and Vanroy, B. (2023a) “Are there just WordNets or also SignNets?” In *Proceedings of the 12th Global WordNet Conference*.

Schuurman, I., Vanroy, B., Vandeghinste, V., Brosens, C., Janssens, M., Declerck, Th. & Bigeard, S. (2023b) *ODWN, OMW: issues when dealing with spoken languages, but especially also with sign languages*. CLIN 33, Antwerp

Sloetjes, H., & Wittenburg, P. (2008). Annotation by category - ELAN and ISO DCR. In: Proceedings of the 6th International Conference on Language Resources and Evaluation (LREC 2008).

Soetemans, L. and Janssens, M.. (2023). Onderzoek naar constituentenvolgorde in Vlaamse Gebarentaal. Enkelvoudige zinnen bij jongeren van 12- tot 18 jarigen. Onderzoeksrapport in het kader van het SignON project, KU Leuven Campus Antwerpen & Vlaamse GebarentaalCentrum (42 pages) (<https://www.vgtc.be/onderzoek/publicaties/onderzoek-naar-constituentenvolgorde-in-vlaamse-gebarentaal/>)

Soetemans, L. and Vermeerbergen, M. (2023). When (shared) space and time don't matter. Remote video-mediated (synchronous and asynchronous) communication in Flemish Sign Language. 2023 IEEE International Conference on Acoustics, Speech, and Signal Processing Workshops (ICASSPW), Rhodes Island, Greece, 2023, doi:10.1109/ICASSPW59220.2023.10193316.

Sutton-Spence, R., & Woll, B. (2007). The Linguistics of British Sign Language: An Introduction. In Language (8th ed.). Cambridge University Press.

Thumann, M. (2013). Identifying recurring depiction in ASL presentations. Sign Language Studies, 13(3), 316-349.

Van Herreweghe, M., Vermeerbergen, M., Demey, E., De Durpel, H., Nyffels, H. & Verstraete, S. (2015). Het Corpus VGT. Een digitaal open access corpus van video's en annotaties van Vlaamse Gebarentaal, ontwikkeld aan de Universiteit Gent i.s.m. KU Leuven. www.corpusvgt.be

Vermeerbergen, M. (1996). ROOD KOOL TIEN PERSOON IN. Morfo-syntactische aspecten van Gebarentaal. [Doctoraatsproefschrift, Vrije Universiteit Brussel].

Vermeerbergen, M. (1997). Grammaticale aspecten van de Vlaams-Belgische Gebarentaal. Gentbrugge: Cultuur voor Doven.

Vermeerbergen, M. (2006). Past and current trends in sign language research. Language & Communication, 26(2), 168–192.

Vermeerbergen, M., Crasborn, O. and Leeson, L. (eds.) (2007). *Simultaneity in Signed Languages: Form and Function*. Amsterdam: John Benjamins.

Vermeerbergen, M. (2010). *Onderzoeksrapport: Woordvolgorde in de Vlaamse Gebarentaal*. Vlaams GebarentaalCentrum.

Vermeerbergen, M., Van Herreweghe, M. Akach, P. & Matabane, E. (2007). Constituent order in Flemish Sign Language (VGT) and South African Sign Language (SASL): A cross-linguistic study. *Sign Language & Linguistics*, 10(1), 23-54.

Volterra, V., Laudanne, A., Corazza, S., Radutsky, E. & Natale, F. (1984). Italian Sign Language: the order of the 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 & Zeitlinger B.V

Wittenburg, P., Brugman, H., Russel, A., Klassmann, A., & Sloetjes, H. (2006). ELAN: a Professional Framework for Multimodality Research. *Proceedings of LREC*. <https://archive.mpi.nl/tla/elan>