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Annotated Video Corpus of FinSL with *Kinect* and Computer-Vision Data

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Abstract

This paper presents an annotated video corpus of Finnish Sign Language (FinSL) to which has been appended *Kinect* and computer-vision data. The video material consists of signed retellings of the stories *Snowman* and *Frog, where are you?*, elicited from 12 native FinSL signers in a dialogue setting. The recordings were carried out with 6 cameras directed toward the signers from different angles, and 6 signers were also recorded with one *Kinect* motion and depth sensing input device. All the material has been annotated in *ELAN* for signs, translations, grammar and prosody. To further facilitate research into FinSL prosody, computer-vision data describing the head movements and the aperture changes of the eyes and mouth of all the signers has been added to the corpus. The total duration of the material is 45 minutes and that part of it that is permitted by research consents is available for research purposes via the LAT online service of the Language Bank of Finland. The paper briefly demonstrates the linguistic use of the corpus.

Keywords: Finnish Sign Language, corpus, annotation, grammar, prosody, *Kinect*, computer-vision

1. Introduction

This paper presents a completed set of Finnish Sign Language (FinSL) material that has been collected in the *CFINSL* project (Corpus project of Finland's sign languages)[1] and processed in the *ProGram* project (a research project that focuses on the grammatical and prosodic investigation of FinSL).[2] The material consists of signed retellings of the stories *Snowman* and *Frog, where are you?*, elicited with the help of text-less picture books from 12 native FinSL signers (8 female, 4 male; ages between 20 and 60 years) and used also in other sign language corpus projects (e.g. Johnston, 2010; Mesch, 2015). The recordings were carried out so that the signers worked in pairs in a dialogue setting in which the recording set-up consisted of 6 Full HD cameras (1920x1080, 25-50 fps) directed toward the signers from different angles (see Figure 1); 6 signers (i.e. one from each pair) were also recorded with one *Kinect* motion and depth sensing input device (see Puupponen et al., 2014). The main video material is available in H.264 compressed MP4 containers. The *Kinect* data is stored and distributed in *OpenNi*[3] and CSV formats.

All the material has been annotated in *ELAN*[4] (Crasborn & Sloetjes, 2008) for signs (see Pippuri et al., 2015), sentence-level translations (see Pippuri, 2015), clauses and their semantic–syntactic structure (including constructed action) as well as for head and body movements (see Figure 2). The annotation work has been carried out by altogether three researchers, all of whom have native competence in FinSL. All the annotations have been checked several times in order to ensure that the work is done to the highest possible standard. To further support the investigation of FinSL prosody, CSV files containing computer-vision data describing the head movements and the aperture changes of the eyes and mouth of all the signers have been linked to the material (Luzardo et al., 2014). The computer-vision data has been produced with the help of *SLMotion*[5] software, a tool specifically developed for the (semi-)automatic analysis of sign language and gestures (Karppa et al., 2014). The total duration of the material is 45 minutes. That part of it that is permitted by research consents is available for research purposes via the LAT – Language Archive Tools online service[6] of the Language Bank of Finland (Finnish *Kielipankki*).

Figure 1: The camera angles of the video material. The signers are labelled *1* and *2*. Signer 1 is always on the left and signer 2 on the right in Cam 1 view.

The details of how the video material was recorded have been presented earlier, in Puupponen et al. (2014). This paper now describes the annotation conventions of the material and the basic characteristics of the additional *Kinect* and computer-vision data. The paper also demonstrates how the present material can be used for linguistic research.

2. Basic Annotation

The basic annotation consists of meaning-based annotations for word (signs) and sentence-level units (translations). Signs are treated as relatively long units (Jantu-

[1] *https://www.jyu.fi/hum/laitokset/kielet/en/research*
[2] *http://users.jyu.fi/~tojantun/ProGram*
[3] *http://www.openni.org*
[4] *https://tla.mpi.nl/tools/tla-tools/elan/*
[5] *http://research.ics.aalto.fi/cbir/software/slmotion/*
[6] *https://lat.csc.fi/*

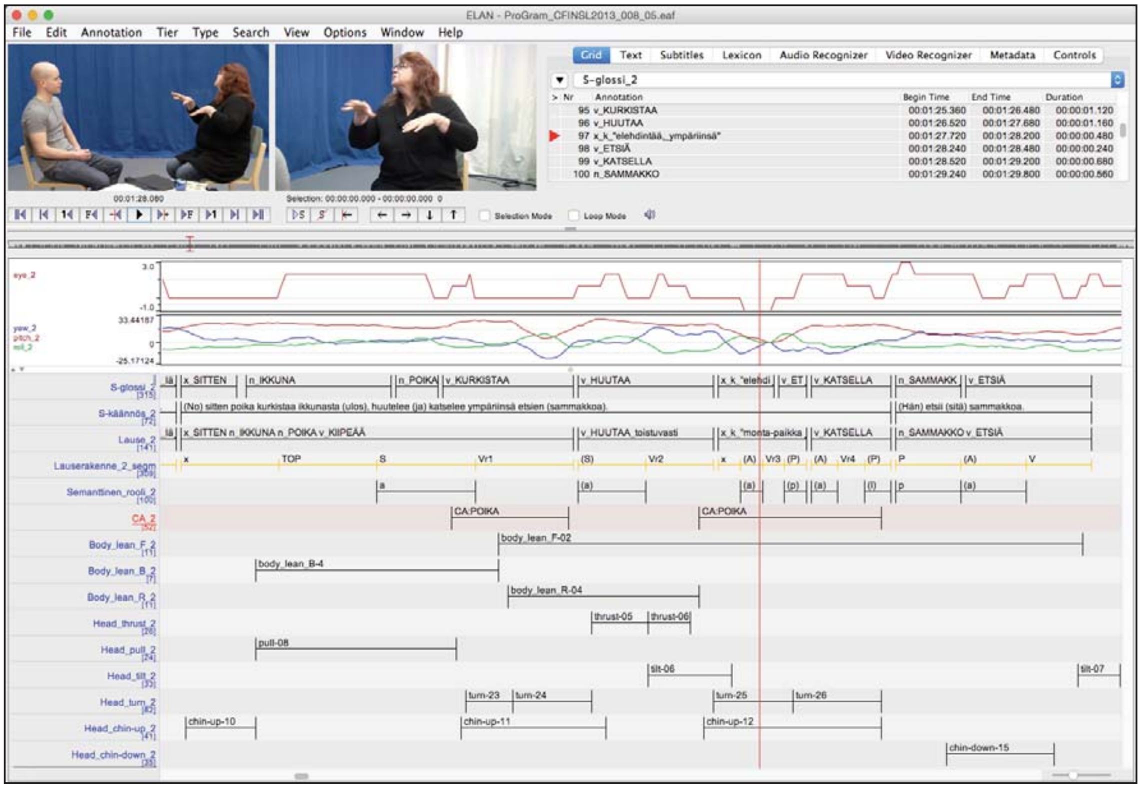

Figure 2: *ELAN* screenshot showing the computer-vision based descriptors for eye aperture changes and head movements (the time series panels), and annotations (the tiers).

nen, 2015a) and defined as distributionally free combinations of form and meaning. They are annotated on the tier *S-glossi* 'S-gloss' (belonging to the linguistic type *Gloss*) in such a way that the same sign is always given the same gloss (i.e. the annotation follows the principle of ID-glossing proposed by Johnston 2008). The glosses on the tier S-glossi (in which the capital S stands for 'systematized') fall into two main categories: *Meaning glosses* (n=3356), i.e. glosses used primarily in the annotation of lexicalized signs and described in a separate Excel-based lexicon (539 lexemes), and *Description glosses* (n=953), i.e. glosses used in the annotation of various depicting signs and gestures. Our syntax of writing both types of glosses is shown in Table 1.

Meaning glosses	prefix(es)_GLOSS(structural info to help distinguish synonyms):meaning-specifier
Examples	n_KENGÄT 'shoes' n_y_VANHEMMAT 'parents' v_JUOSTA(BB) 'run' v_EI-HALUTA 'does not want' v_ANTAA:minulle 'give to me' x_SITTEN 'then'
Description glosses	prefix(es)_k_"description"
Examples	v_k_"poika-liikkuu" 'boy moves' n_k_"puunrunko" 'shape of a trunk'

Table 1: Our syntax of writing glosses.

Glosses contain prefixed information about the major word-class of the sign (i.e. whether the sign is a nominal *n* or a verbal *v*, or unspecified *x*; see Section 7). In our meaning-based annotation (cf. form-based annotation, e.g. Johnston, 2016), the category is decided on the basis of the linguistic context (see Pippuri et al., 2015). Consequently, we distinguish, for example, between TYÖ 'work' (a nominal) and TEHDÄ 'to work' (a verbal), regardless of their fairly similar forms in FinSL.

If two or more signs are used in combination to refer to a single concept, they are analyzed as compounds (*yhdiste* in Finnish) and annotated with a single gloss, with the prefix *y* following the word-class prefix. Synonymous signs are distinguished by adding structural information (based on Rissanen, 1985) about the handshape(s), location or movement in parenthesis after the main gloss. Semantically negative signs are indicated with the Finnish verb *ei* 'no' at the beginning of the main gloss.

Pointing signs (glossed as OS 'pt', abbreviated from Finnish *osoitus* 'pointing') and the palm-up gesture (PALM-UP) are both treated as semantically and formally independent units and annotated without any information prefixed to them. However, the glosses of pointing signs may contain suffixed information about the semantics or form of the pointing (e.g. OS:minä 'me', OS:tuo 'that', or OS(B) 'pointing with a B-handshape').

Finnish translations are annotated on the level of sentences on the tier *S-käännös* 'S-translation' (belonging to the linguistic type *Translation*). As has been described in

Jantunen (2009), FinSL sentences cannot be defined comprehensively by any formal criteria. Consequently, the identification of translatable sentences has relied a lot on the intuitions and semantic insights of the annotators.

The guiding principle of the translation process has been as far as possible to maintain structural correspondence between the original signed sentence and its Finnish translation. In order to follow this principle to the maximum, the translations include additional information about what elements have been elided from the signing as well as what elements present in the Finnish translation are not expressed in the signing in the first place (both are indicated with parentheses). In addition to this, the translations also show what elements in the signing are expressed via constructed action and with other (often nonmanual) mimical behavior (this is indicated with square brackets). For example, the Finnish translation *(Poika) [menee takaisin ulos] (ja jatkaa lumiukon) tekemistä* 'the boy goes back out and continues to make the snowman' shows that the theme *poika* 'boy' is not expressed lexically, and that there is no lexical material in the original signed version that expresses the meaning 'and continues [to make] the snowman' either. The translation also shows that expression of the meaning 'going back out' relies on the use of constructed action. A detailed description of the translation procedure and conventions is presented in Pippuri (2015).

3. Syntactic and Semantic Annotation

Signs are grouped into clauses on the tier *Lause* 'clause' by following the conception of the clause summarized in Jantunen (2013, 2016). A selection of clauses that are formed around a verbal predicate are then further analyzed for their syntactic and semantic structure. The syntactic structure (for the productions of 10 signers; n=1077 clauses) is annotated on the single tier *Lauserakenne* 'clause structure'. In the standard case, clauses are analyzed into predicates (V) and their core arguments: S, the single core argument of an intransitive clause; A and P, the primary and secondary core argument of a transitive clause, respectively; and E, the third core argument of a ditransitive clause. The analysis is done also in cases where the core argument is not expressed overtly. In such cases – that is, when the semantics of the predicate requires a core argument to be present but it is not expressed – the symbol of the core argument is written in parentheses and linearized by routinely following the SV, AVP or AVPE scheme.

An exception to the standard case in the annotation of clause structure is the annotation of clauses that have a Type 3 verbal as their predicate (Type 3 verbals resemble Liddell's 2003 depicting verbs and they are annotated typically with description glosses; see Section 7). Very often such clauses are composed only of the verbal sign. Analytically, the (classifier) handshape(s) of the verbal can be treated as the core argument(s) of the clause (cf. head-marking; Nichols, 1986; Jantunen, 2008), and the core argument analysis can be extended to cover the layered nonmanual behavior, too (Ferrara & Johnston, 2014). As such core arguments are not free lexical units but rather nominal morphemes fused to the verbal head, or nonmanual gestural expressions occurring simultaneously with the Type 3 verbal, they are indicated in the annotation with lower-case letters connected to the predicate symbol (e.g. sV, aVp). A summary of the annotation symbols used in the annotation of clause-internal core elements (i.e. the predicate and its core arguments) is given in Table 2.

Symbol	Description
V	The verbal predicate of the clause.
S, A	The primary core argument of an intransitive or a transitive clause, respectively.
P	The secondary core argument of a transitive clause.
E	The third core argument of a ditransitive clause.
sV, aVp	A predicate that is a Type 3 verbal. The verbal is a well-formed clause on its own. The classifier handshape(s) of the verbal and the layered nonmanual behavior are analyzed as the core argument(s) of the clause.
( )	Parenthesis indicates that the core argument has been omitted.

Table 2: The annotation symbols of the clause-internal core elements.

In addition to the main elements described above, clauses may also contain other types of elements. The symbols used in their annotation are summarized in Table 3.

Symbol	Description
a	Typically a clause-final pointing that is co-referential with the A argument.
v	An auxiliary-like secondary predicate.
x	A syntactically peripheral element or constituent whose function/internal structure is left unanalyzed (e.g. a question sign, a conjunction sign, an adjunct).
N	A clause-internal nominal constituent that often complements the meaning of the classifier handshape(s) of Type 3 verbals.
TOP	Typically a left-detached clause-external topic constituent that sets an interpretative framework for the following clause.
e	An error or a false start.

Table 3: Additional symbols used in the annotation of clause-internal elements.

Clausal coordination (i.e. the linking of two or more clauses of the same rank) as well as subordinated complement clauses (i.e. full clauses that function typically as P arguments) have also been indicated in the annotation (for a discussion, see Dixon, 2006; Haspelmath, 2007; Jantunen, 2016). In practice, this has been done indirectly by adding extra symbols to the end of the main predicate symbol V. Clausal coordination is indicated with the lower-case letter *r* (from Finnish *rinnastus* 'coordination') and this is followed by the number of the clause in the coordinated sequence (e.g. Vr1, Vr2). The subordination of complement clauses, on the other hand, is marked in the predicates of both the matrix clause and the complement clause: in the matrix clause the predicate symbol is appended with the matrix marking letter *m* (i.e. Vm) whereas in the complement clause the added letter is the complement (Finnish *komplementti*) marking *k* (i.e. Vk; the complement clause may also be nominally headed, in which case it is annotated holistically as Nk). The symbols of coordination and subordination may be combined (e.g. Vr2m, which indicates the predicate of the second coordinate clause, also taking a clausal complement).

Two other types of coordination have also been taken into account in the syntactic annotation. These are the coordination of predicates (cf. serial verb constructions; Velupillai, 2012) and the simultaneous coordination of two Type 3 verbals/clauses, each one expressed with a different hand. The coordination of predicates is indicated simply with a number following the predicate symbol (e.g. V1, V2). The primary indicator of simultaneous coordination is the *plus* sign (e.g. Vr1+sVr2). Table 4 summarizes the symbols used in the annotation of coordination and subordinated complement clauses.

Symbol	Description
Vr	The predicate of a coordinated clause.
Vm	The predicate of a matrix clause.
Vk	The predicate of a complement clause.
Nk	A nominally headed complement clause.
V1,V2	Coordination on the level of verbal predicates is indicated with a number directly attached to the predicate symbol.
+	Two-handed simultaneous coordination of two clauses manifested as Type 3 verbals is indicated with a plus sign.

Table 4: The annotation symbols of coordination and subordinated complement clauses.

In some cases it is necessary to simply indicate that a certain sequence is a certain type of clause. The symbols used for this purpose are presented in Table 5.

Symbol	Description
[ ]	A sequence that forms a clause.
advl	An adverbial clause.
rell	A relative clause.
upol	An embedded clause.
ketl	An undefined chain of clauses.

Table 5: The annotation symbols for clause-level units.

The semantic structure of clauses has been annotated (for the productions of 6 signers) in terms of the basic semantic roles of the core arguments. The annotation is done on the tier *Semanttinen_rooli* 'semantic role', which follows the symbolic subdivision of the annotations on the tier *Lauserakenne_segm*, created on the basis of the tier *Lauserakenne* (i.e. the tiers Lauserakenne and Lauserakenne_segm contain essentially the same information, the only difference being the way the information on the tiers is structured). A summary of the semantic roles used and their symbols is given in Table 6; the roles are based on Givon (2001), Ojutkangas et al. (2009) and Velupillai (2012).

Symbol	Description
a	Agent
p	Patient
r	Recipient
e	Experiencer
b	Benefactor
i	Instrument
l	Location
s	Source
g	Goal
t	Theme

Table 6: The annotation symbols for semantic roles.

Periods of constructed action and constructed dialogue (see Ferrara & Johnston, 2014; Hodge & Ferrara, 2014) have also been annotated in the material (for the 6 retellings of the story *Frog, where are you?*); these annotations are written on the tiers CA and CD, respectively. The annotation of constructed action and constructed dialogue follows the conventions established for Australian Sign Language (Johnston, 2016). In practice, this means that the notations CA and CD are suffixed with information about whose actions or dialogue is being enacted or reported (e.g., CA:POIKA 'the actions of the boy' or CD:LUMIUKKO 'the speech of the snowman').

The linguistic type of all the tiers used in the syntactic and semantic annotation is *Research*. The only exception to this rule is the tier Lauserakenne_segm which, due to its symbolic subdivision, belongs to the linguistic type *Structure*.

4. Nonmanual Annotation

In order to facilitate research into FinSL prosody, the material has been annotated on a low level for various types of head and body movements. The annotation of head movements is roughly based on the categorization presented in Puupponen et al. (2015) and makes a distinction between 10 types of head movements (e.g. *nods, tilts*). The number of distinctively annotated body movement types in the material is 9 (e.g. *body tilts, shoulder shrug*). Table 7 presents a summary of the tiers used in the annotation of head and body movements; the linguistic type of all the tiers is *Nonmanual*.

Head movement tiers	Body movement tiers
Head_nod	Body_lean_F[orward]
Head_nodding	Body_lean_B[ack]
Head_thrust	Body_lean_R[ight]
Head_pull	Body_lean_L[eft]
Head_tilt	Body_turn_R
Head_shake	Body_turn_L
Head_turn	Body_tilting
Head_tilting	Body_shoulders_up
Head_chin-up	Body_shoulders_shrug
Head_chin-down	

Table 7: The tiers representing the low-level types of annotated head and body movements.

The nonmanual annotation has been done with the help of all the 6 camera angles (i.e. a particular movement may be visible only from one angle). That the annotations are low level means that they are not organized hierarchically into more abstract classes.

5. *Kinect* Data

One of the informants in each pair has been recorded with a *Kinect* sensor. As described in Puupponen et al. (2014), the purpose of recording *Kinect* data has been to complement the video with quantitative information about depth, a dimension not inherently present in traditional video recordings (recording done with a ceiling camera being, of course, an exception). In practice, the *Kinect* data consists of a low-quality RGB video, augmented with a 16 Hz infrared video, and a skeleton model of the signer (Figure 3). Of these, the infrared video allows one to investigate the signer's activity in the dimension of depth to the precision of one millimeter. The skeleton data, on the other hand, adds further value to the analysis of the signer's movements as it provides data analogous to that collected with motion capture equipment (see Jantunen et al., 2012).

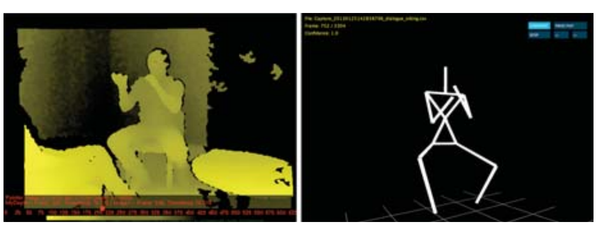

Figure 3: Screenshots from the *Kinect* data showing the infrared video (left) and a skeleton model of the signer (right) (Puupponen et al. 2014).

The *Kinect* data is not currently linked to the main data in *ELAN*. The infrared recordings can be investigated with specially coded *NiRecorder* software, based on *OpenNi* technology. The numerical skeleton model data is stored in Comma Separated Value (CSV) files, which can be easily imported into common mathematical software, such as *Matlab*, for further analysis.

6. Computer-Vision Data

A novel feature of the completed material is that the videos of each signer recorded from the near frontal angle (Cams 4 and 5, see Figure 1) have been automatically processed with computer-vision technology implemented in the *SLMotion* software specifically developed for the motion analysis of sign languages (Karppa et al 2014). With *SLMotion*, we have been able to estimate the movement of the signer's head in three dimensions as well as the relative degree of openness of the signer's eyes and mouth (Luzardo et al. 2014). This quantitative information, contained in *SLMotion* produced CSV files, has been linked into *ELAN*, where it can be visually inspected in the time series panels together with the annotations (see Figure 2). The computer-vision data can be used directly in the analysis of the interplay between prosody and syntax and the visualizations are also helpful in detecting potentially interesting sequences within the video material.

The movement of the head is estimated in three dimensions: *yaw*, *pitch*, and *roll*, which associate with turning-like movements, nodding-like movements, and tilting-like movements, respectively (Figure 4). The estimate is based on a combination of techniques which result in the detection of the signer's face and, for example, the corners of their eyes and the mouth (Luzardo et al., 2014). On the basis of this information, *SLMotion* is able to calculate the geometrical angle of the head (in the three dimensions) for each video frame (Figure 5).

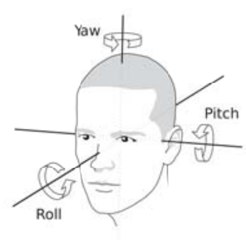

Figure 4: The three dimensions of human head motion (Jantunen et al. 2016b).

The estimation of the openness of the eyes and mouth is a classification task based on techniques similar to those used for the estimation of head movement (Luzardo et al., 2014). For the classification of eye aperture, *SLMotion* uses four classes: eyes *shut* (e.g. in blinks), eyes *squinted*, eyes *neutral*, and eyes *wide open*. The classification of mouth aperture is estimated separately in horizontal and vertical dimensions. For the horizontal dimension, the classes are *narrow*, *relaxed* and *wide*. For the vertical dimension, the classes are *closed*, *open* and *wide*.

In addition to the numerical data on the head movements and the classes of aperture changes of the eyes and mouth of the signers, *SLMotion* also indicates the exact method it has used in making the estimate. This information is valuable for research as it can be used to assess the reliability of the automatically generated estimates.

Figure 5: A visualization of the calculation of the head pose angle in yaw, pitch and roll dimensions for three different video frames (Jantunen et al. 2016a).

7. Exploitation of the Material

The material has been prepared so that it can be used in answering many types of research questions, both grammatical and prosodic. To begin with, a lot of information can already be derived from the annotations themselves. For example, as each sign is tagged for word-class, a few simple regular expression searches targeting the tier S-glossi can be used to collect information about the frequency of nominal and verbal signs in the material. The results of such a search are demonstrated in Figure 6, which shows both the overall percentual share of nominal and verbal signs in the whole material (signing from 12 signers containing altogether 4309 signs) as well as the internal composition of the classes nominal and verbal in the data. Note that in Figure 6 all the pointing signs are grouped into the class of nominals (Jantunen, 2010). On the other hand, all PALM-UP gestures are treated as unspecified in terms of category.

In research into FinSL (e.g. Jantunen, 2008, 2010, 2013, 2016), the categories of nominal and verbal have been defined by semantic and grammatical criteria such as reference (nominals refer to entities, verbals to temporally manifested dimensions of events), the marking of aspect (the markers of aspect and Aktionsart distinctions attach only to verbals), and distribution in clauses (the position of verbals in clauses is more constrained than that of nominals). Both categories can be further divided into subclasses, of which the three subclasses of verbal signs – Type 1, 2 and 3 verbals (resembling plain, indicating and depictive verbs of Liddell, 2003, respectively; see Jantunen, 2010, for a full discussion of the differences) – are the most researched ones (see Section 3).

In the future, the syntactic, semantic and nonmanual annotations will be exploited extensively in the investigation of, for example, word-order, ellipsis, syntactic functions (i.e. subject and object) and the interplay between clausal structure and constructed action in FinSL.

Thanks to the additional *Kinect* and computer-vision data, the present corpus can also be used in research into grammar and prosody in more novel ways. First, the added data can be exploited as supporting material in qualitative investigation of the interplay between syntactic structure and prosody. An example of such an investigation was the research into clausal coordination in FinSL by Jantunen (2015, 2016; also Jantunen & De Weerdt, 2016). This work explored primarily the purely grammatical properties of conjunctive ('and'), adversative ('but') and disjunctive ('or') clause linkage. However, in addition to this, the study also exploited the computer-vision data on head movements together with human-made annotations to discover systematic patterns of head motion in conjunctively coordinated complex sentences. Through a visual observation of the head movement descriptors for yaw, pitch and roll in *ELAN* (see the view in Figure 2), a recurring pattern of a back and forth head movement in the roll dimension was identified in the study. A functional analysis of this tilting-like movement revealed that signers used it to increase the prosodic cohesion of the clauses involved in the process of conjunctive coordination.

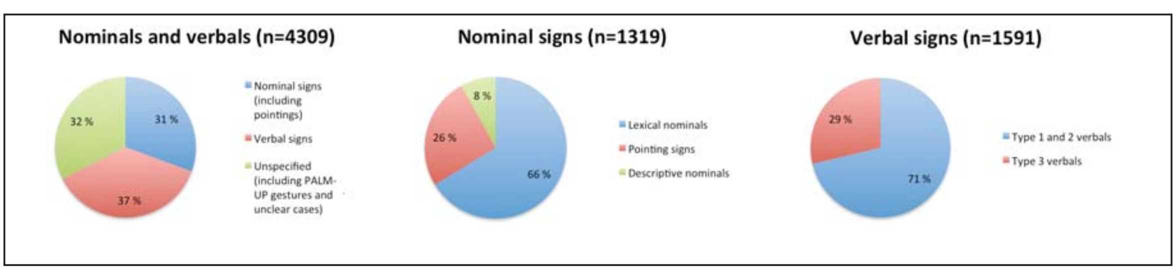

Figure 6: The distribution of nominals and verbals in the material.

The additional *Kinect* and computer-vision data can also be exploited directly in the quantitative investigation of prosody. An example of this type of study is the work by Jantunen et al. (2016ab) which investigated, with similarly collected and processed data from Swedish Sign Language (SSL), the rhythm of head movements in a small sample of semantically and structurally comparable FinSL and SSL sentences. In the study, altogether 8 FinSL and 8 SSL sentences, all extracted from retellings of the story *Snowman*, were first divided automatically into three sequences in *ELAN*. After this, the numerical signer-specific computer-vision data was used to calculate a language-specific range value for yaw, pitch and roll in each sequence. The information that was found was then used to investigate similarities and differences in the amplitude (cf. smallness, bigness) of the head movement in the sentences of the two languages.

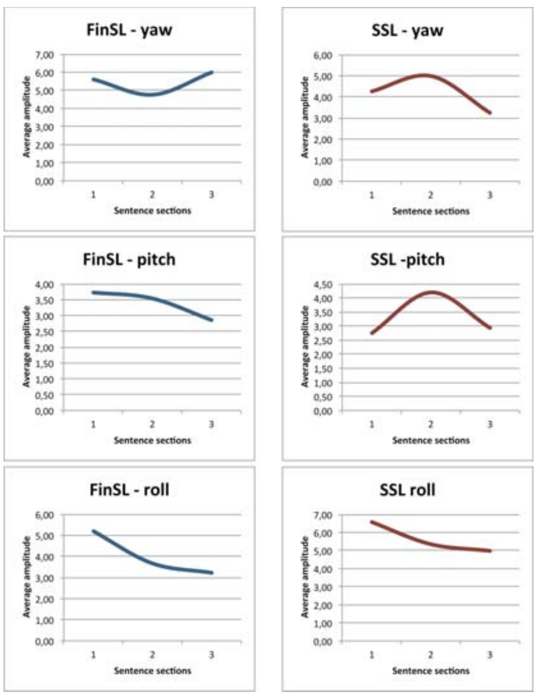

Figure 7: The average amplitude (in degrees) of the head movement in yaw, pitch, and roll dimensions for the three sections of 8+8 comparable FinSL and SSL sentences (Jantunen et al. 2016ab).

The main results of Jantunen et al.'s (2016ab) study are summarized in Figure 7. While the language-specific amplitude curves were different in both yaw and pitch dimensions (correlation co-efficient r=-0.95 and r=0.19, respectively), the curves were identical in the roll dimension (r=1.0; i.e. a perfect positive correlation). This identicality tells us that, in both languages, the movement of the head in the roll dimension was larger in the early parts of the analyzed sentences than in the final parts, and that there is a rhythmic similarity between the two languages concerning the way the head moves in the roll dimension in these sentences.

8. Conclusion

This paper has presented an annotated video corpus of FinSL to which has been added *Kinect* and computer-vision data. We have described how the material has been annotated for signs, sentence-level translations, syntactic and semantic structure, and for nonmanual activity. Moreover, we have outlined the basic characteristics of the additional *Kinect* and computer-vision data and given examples of how this material can be exploited for linguistic purposes. In the future, more layers and features will be added to the material. We are convinced that, eventually, this type of multidimensionally processed material will help us deepen our understanding of FinSL grammar and prosody by making it possible to ask completely new kinds of research questions.

9. Acknowledgements

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