

Do repeated references result in sign reduction?

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Previous research on speech and gesture has found that repeated references are often linguistically reduced in terms of, for example, the number of words and the acoustic realization of these words, compared to initial references. The present study looks at the production of repeated references by 14 signers of Sign Language of the Netherlands (NGT). Participants had to describe figures to an addressee, who had to pick the correct figure from a large group of figures. Several figures had to be described several times. The question was whether there would be reduction in the repeated references. We found systematic effects of repetition in that repeated references were shorter, contained fewer signs, and shorter signs than initial references. Moreover, in order to measure sign precision, a perception test was used where participants had to judge, in a forced choice task, which sign they considered to be the most precise, looking at 40 pairs of video clips with signs produced in either initial or repeated references to the same object by the same signer. We found that, non-signing participants (but not signing participants) consider signs produced during repeated references to be less precise than the signs produced during initial references. Taking together these results suggest that a similar reduction process in repeated references occurs in NGT as has been found previously for speech and gesture.

Keywords: sign language, repeated reference, reduction

1. Introduction

Variability is ubiquitous in speech production, with words never pronounced in exactly the same way more than once. For example, someone might first pronounce the phrase ‘of course’ slowly and precisely, followed by an instance where it is pronounced quickly, less precisely, and more like ‘fcourse’ (Ernestus & Warner 2011). This example of language variability shows that language can be reduced (in

this case by shortening and merging words). While various studies have looked at reduction in speech, reduction in signs remains largely unexplored, partly because it was unclear how sign reduction can be measured. The present study addresses this point.

Little experimental research has been done on reduction in sign language. Tyrone and Mauk (2010), as a notable exception, looked at sign lowering (in American Sign Language), which can be seen as an instance of reduction. Sign lowering, according to Tyrone and Mauk, occurs when “a sign [is] being produced in a lower location than in the citation form” (Tyrone & Mauk 2010: 317). In their study, they found that several phonetic factors, such as production rate, influence the exact location of the produced sign. The question is whether there may be other factors causing signs to be reduced as well, and whether there are, apart from location, other ways in which signs can be reduced. Previous research on speech (e.g. Bard et al. 2000; Fowler 1988; Fowler & Housum 1987) has shown that when speakers produce a repeated reference, this repeated reference is often shorter and uttered less clearly, and thus becomes less intelligible for the listener than an initial reference. In other words, the repeated reference is reduced compared to the initial reference. In the present study, we will combine these two strands of research (on sign language and on speech) by looking at reduction in signs in repeated references. Repeated references are a suitable domain to study sign reduction, since they are a naturally occurring phenomenon, produced whenever the same object is described more than once, but can also be elicited in a controlled manner, especially in an experimental setting. The present study will look at repeated references in signs produced by speakers of Sign Language of the Netherlands (NGT). Speakers of NGT produced repeated references in an experimental setup, allowing measurement of several aspects of signs that may be reduced, such as sign duration and sign precision.

1.1 Reduction in spoken repeated references

In conversation, people often produce referring expressions to describe objects in the world around them, for example when describing a building that they recently visited. The production of repeated references occurs when people refer to the same object more than once in the conversation. In the example case of a building being described, one can imagine that in an initial description many details of the building are mentioned, such as its exact location, orientation, size and colour. In a repeated description in the same conversation many of these details may be left out because the conversational partner already knows which building is being discussed. This means that descriptions of the same object can range from “the tall brown building at the back of the university campus” to “the building”. Indeed,

research has found that in speech, these repeated references are often reduced in at least two ways (Aylett & Turk 2004; Bard et al. 2000; Brennan & Clark 1996; Clark & Wilkes-Gibbs 1986; Fowler 1988; Fowler & Housum 1987; Galati & Brennan 2010; Lam & Watson 2010). Firstly, repeated references to the same target object usually contain fewer words than initial references (Clark & Wilkes-Gibbs 1986; Galati & Brennan 2010), as can be seen in the example above where in the repeated reference the information on the building's size, colour and location are omitted. Brennan and Clark (1996) claim that this is due to the fact that people establish so-called "conceptual pacts" as more common ground is established over the course of the conversation.

Secondly, repeated references often contain repeated words, and we know from earlier studies that these are often reduced acoustically (Aylett & Turk 2004; Bard et al. 2000; Fowler 1988; Fowler & Housum 1987; Lam & Watson 2010). This acoustic reduction may be due to the fact that repeated references can be claimed to be (partly) redundant, since (some of) the words have already been mentioned before. Several decades ago, Lieberman (1963) claimed that redundant words are shorter and perceived as less intelligible when taken out of context and presented to listeners. Fowler and colleagues (Fowler 1988; Fowler & Housum 1987) found that repeated, redundant, words are indeed shortened. Samuel and Troicki (1998) also showed that redundant speech is articulated less clearly, and, more recently, Aylett and Turk (2004), in their work on the smooth signal redundancy hypothesis, found an inverse relationship between redundancy and duration, with more redundant speech having a shorter duration. Research by Lam and Watson (2010) provided additional evidence that repeated references have reduced prominence and are also reduced in duration, compared to initial references (see also Bell et al. 2009). Words from repeated references, when taken out of context and presented to a listener, have also been found to be less understandable for the listener because their pronunciation is less clear in repeated references than in initial references (Bard et al. 2000; Galati & Brennan 2010). This reduction in repeated references that has been found in research on speech can also be related to previous work on the influence of discourse status on the form of referring expressions (Gundel, Hedberg & Zacharski 1993), in that repeated references are more likely to be realized in the form of more attenuated expressions (e.g., a pronoun instead of a description).

It is thought that reduction in referring expressions may be due to speaker's efficiency, in production and planning processes (Arnold 2008; Arnold, Kahn & Pancani 2012; Bard et al. 2000; Bard & Aylett 2005; Ferreira 2008), and in communicative strategies (e.g. Aylett & Turk 2004; Fenk-Oczlon 2001; Lieberman 1963; Lindblom 1990; Zipf 1936). The use of communicative strategies, with speakers as efficient language users, has been demonstrated in a range of studies (for an

overview, see Jaeger & Tily 2011). Back in 1936, Zipf proposed his Principle of Least Effort, which states that language users prefer to take the least effort necessary to get a message across. Shannon's noisy channel model (1948) can also be related to this reduction process, where, given the context, the more probable a word is, the more likely it is to be reduced in its linguistic form. Lindblom (1990), in his theory of hyper- and hypo-speech, claims that speakers adapt to the listener's needs, meaning that redundant speech is reduced as long as 'sufficient discriminability' remains. As mentioned above, more recent work on acoustics, by Aylett and Turk (2004), among others, has found that predictable words are indeed reduced, at least with regard to duration. Jaeger (2010) proposed the hypothesis of Uniform Information Density (UID), which states that "speakers prefer utterances that distribute information uniformly across the signal (information density)" (Jaeger 2010: 25).¹ What this means is that elements of an utterance with a relatively high information value, for example due to the fact that the element is new or specifically important in the conversation, are lengthened. Likewise, elements with relatively lower information value, for example, elements that contain old information and/or are not that important for successful communication, are shortened. This way, the amount of information that is transmitted in the utterance becomes more uniform and optimal for speaker and addressee. These ideas of language efficiency can also be considered to be in line with Grice's (1975) Maxim of Quantity, which states that speakers make their "contribution as informative as required (for the current purpose of the exchange)" and proposes to speakers to "not make your contribution more informative than is required".

It can be argued that the reduction in repeated references that previous studies have found is due to the abovementioned processes: when speakers produce repeated references, they fully reproduce those (auditory) aspects of the referring expression that contain important or new information and are necessary for quick target identification. The less informative and more predictable aspects of the referring expression may be omitted, leading to reduced references.

1.2 Reduction in visual repeated references: gesture and sign language

The idea that predictable linguistic material is reduced has been applied to several aspects of speech communication, such as syntax (Jaeger 2010) and phonetics

1. One of the reviewers suggested that the idea behind the UID hypothesis may be related to another principle of 'cognitive economy', namely Menzerath's law (Altmann 1980), which roughly states that "the bigger the whole, the smaller the parts". An example is that "words composed of a high number of syllables tend to be composed of a "relatively" low number of phonemes" (Fenk & Fenk-Oczlon 1993: 11).

(Bard et al. 2000). Taking into account that communication not only involves verbal aspects such as syntax and phonetics, but can also contain or consist of visual aspects such as gestures (Kendon 2004; McNeill 1992) or signs (Stokoe 2005), we may wonder whether a reduction process such as described above also occurs for the visual domain.

Relevant previous research on gesture has looked at the effect of common ground (Gerwing & Bavelas 2004; Holler & Wilkin 2009) and repeated references (de Ruiter, Bangerter & Dings 2012; Hoetjes, Koolen, Goudbeek, Krahmer & Swerts 2011) on gesture production, albeit with somewhat inconclusive results. Gerwing and Bavelas (2004) found that gestures that were produced when there was common ground were less complex, less informative and less precise than gestures produced when there was no common ground. Holler and Wilkin (2009) found that utterances contained “less semantic information when common ground exists”, while gestures appeared to “carry a greater communicational weight due to a higher gesture rate” (Holler & Wilkin 2009: 285). When we look at repeated references, de Ruiter et al. (2012), when testing their trade-off hypothesis, found that repetition did not affect gesture rate (in number of gestures per 100 words). Hoetjes et al. (2011) found that both speech and gesture were affected in repeated references. Speech was reduced with regard to semantics, number of words and overall duration of the referring expression; gestures were reduced with regard to their absolute number, but increased in their rate (in number of gestures per 100 words).

What most of the studies looking at gesture have in common is that they take two modalities into account, both speech and gesture. Looking at both modalities is inherent to studies on co-speech gestures since gestures are closely integrated with speech, on a semantic, temporal, and pragmatic level (Kendon 2004; McNeill 1992). The question for these types of research is often what the exact relationship between speech and gesture is and what the role of each modality is in the discourse (Kelly, Manning & Rodak 2008; Krahmer & Swerts 2007). When we consider sign language, research naturally tends to focus mainly on one modality, the visual modality. There has been a range of research on phonological and phonetic aspects of sign language (Brentari 1998; Crasborn 2001; Johnson & Liddell 2010; Liddell & Johnson 1989; Sandler 1989; Sandler & Lillo-Martin 2006; Schembri et al. 2009; Tyrone & Mauk 2010; van der Hulst 1993), starting with Stokoe’s seminal work from 1960, proposing that signs in sign languages consist of three main parameters (handshape, location, and movement; see Stokoe 2005). Few studies have looked at sign language from the perspective of efficient language use, although some studies discussed the efficient use of the different modalities when producing sign language as compared to speech (Gee & Goodhart 1988; Klima & Bellugi 1979; Leuninger, Hohenberger, Waleschkowski, Menges & Happ 2004). More particularly, these studies suggest that due to the difference in modality, speech, on

the one hand, tends to consist of many small chunks, each containing relatively little information, whereas sign language, on the other hand, usually consists of fewer but bigger chunks, containing more information. This effect of modality has also been related to differences between speech and sign in production speed and processing manner (Brentari 2002; Klima & Bellugi 1979; Leuninger et al. 2004).

In the light of efficient language use, it is interesting to see how signs behave with regard to reduction in repeated references. In particular, we may wonder whether signs are reduced in ways which are comparable to speech and/or to co-speech gestures. On the one hand, considering that signs, like words, usually convey lexical meaning, it might be the case that reduction in sign is similar to reduction in speech, for example with regard to the semantics that are expressed. On the other hand, signs, unlike words, but like co-speech gestures, are a means of communication in the visual domain, and there may be aspects of reduction that are modality-specific and thus alike between signs and co-speech gestures. Of course, it could also be the case that signs are not reduced in a way comparable to speech or to co-speech gestures, but that signs, if they are reduced, are reduced in a sign-specific manner.

Only a handful of previous studies have looked at reduction in sign language. Tyrone and Mauk (2010), studying phonetic reduction in American Sign Language (ASL), looked at the production of the sign *WONDER* in two phonetic contexts and at three signing rates. Their results show that sign lowering (which can be seen as a form of efficiency) occurs with increasing signing rate and can (but does not necessarily) occur in specific phonetic contexts. Another experimental study, by Mauk, Lindblom & Meier (2008), focusing on undershoot² in ASL also found that signing rate had an effect on the exact location in which a sign was produced, with this effect differing depending on the linguistic context. Other studies on variation in sign language, by Schembri et al. (2009) and by Russell, Wilkinson & Janzen (2011), looked at naturally occurring data and also found that sign location can vary, with signs being produced at lower locations than their citation form. However, none of these studies takes repetition into account as one of the factors influencing sign production.

1.3 Present study

In the present study, we look at NGT signs, to see whether reduction in repeated references, as previously found for speech and gesture, also occurs in sign language. Considering that NGT is a fully fledged sign language and presumably behaves in many respects like a spoken language, we hypothesize that, as in speech,

2. Undershoot is a phenomenon comparable to reduction, which occurs “when an expected phonetic target is not achieved [...]” (Mauk, Lindblom & Meier 2008: 4).

reduction in repeated references will occur. The question is, of course, how reduction in signs can be measured. Considering the fact that the aim is to compare possible reduction in sign language with reduction in speech and gesture, we measure reduction by combining methods that have been used previously in studies on speech and on gesture. We will look at sign characteristics that we consider comparable with some of the aspects of speech that have been studied previously when looking at reduction (as discussed above), namely number of words, utterance duration, and word duration. We will also take precision into account, which has been done in previous studies (as discussed above) on gesture. Therefore, in the present study on sign language, we use methods that can be applied both to sign language and to spontaneous co-speech gestures. We will analyse the number of signs, the utterance and sign duration, and sign precision. We conducted a production task to analyse the number of signs, utterance duration, and sign duration (Section 2). Following Hoetjes et al. (2011), we conducted an additional perception task to analyse sign precision (Section 3). Details of both the production and perception task are given below.

2. Experiment I: production experiment

To study reduction in repeated references in NGT, a data set was created consisting of recordings of participants taking part in a director-matcher task. In this task, the director had to describe a number of objects in such a way that the matcher could identify them from a range of similar looking figures. In the stimuli, there were several figures that had to be described multiple times, leading to repeated references to the same item.

2.1 Participants

The director-matcher task was done by a total of 14 signers of NGT. The group of participants consisted of five male and nine female speakers, with an average age of 46 years old (range 26–60 years old). Of the 14 participants, nine were deaf since birth. The average length of time that the participants had been signing NGT was 23.5 years (range 2–50 years). Two participants learned NGT from birth, three learned NGT before the age of 5, and nine participants learned NGT after age 10. The participants who had been signing NGT the longest were not necessarily the signers who were born deaf. Participants took part twice in the experiment; first they were randomly assigned the role of either director or matcher, and they would switch roles after doing the experiment once, so that each participant acted as director once.

2.2 Stimuli

Two picture grids, each containing 16 pictures, were used by each director. For each picture grid used by the director, an alternative grid was constructed for the matcher, containing the same items as on the director's picture grid, but for the matcher, the items were numbered and presented in a different order (for example grids, see Figures 1 and 2). The picture grids showed either pictures of people or of furniture items. The two different domains (people and furniture) were used since previous studies on referring expressions had shown them to be efficient domains for making people produce referring expressions (Koolen, Gatt, Goudbeek & Kraemer 2011; Van Deemter, Gatt, van der Sluis & Power 2012; Van der Sluis & Kraemer 2007). The items of the furniture picture grid were the same as those used in the TUNA and D-TUNA corpus (Koolen et al. 2011; Van Deemter et al. 2012); the items of the people picture grid were inspired by the items from the people domain in these same corpora.



Figure 1. Example of a people picture grid. The picture with the red square surrounding it is the target object of that particular trial.



Figure 2. Example of a furniture picture grid. The object with the red square surrounding it is the target object of that particular trial.

Since the participants would do the experiment twice, once in the role of director and once in the role of matcher, two sets of picture grids (i.e. four picture grids in total) were used, with different pictures on each picture grid. A participant would see one of a set of picture grids when taking part in the role of the director and the other set of picture grids when taking part in the experiment in the role of the matcher. Each picture grid was used for 15 trials, adding up to a total of 30 trials for each director. For the first 15 trials, one of the people picture grids was used, for the last 15 trials one of the furniture picture grids was used. In each trial, there was one target object (marked by a red square), which was surrounded by 15 distractor objects, and which had to be described by the director. The crucial manipulation in the task was that several pictures had to be described repeatedly: in each of the picture grids, two pictures had to be described twice, and two pictures had to be described three times. Repeated references to the same object were never one straight after the other, which means that descriptions of other objects were given in between the initial and repeated descriptions of the critical objects. The use of different sets of picture grids means that although a matcher would become familiar with the type of pictures of people and furniture used in the experiment as they were described by the director, he or she would have to describe a new set of pictures of people and furniture once the roles were switched. Throughout the

experiment, it was clear to the directors that several pictures had to be described repeatedly. An example of an initial object description (in this case of a large red chair, as shown in Figure 2) is given in (1).

- (1) CHAIR, RED, NOT TO-THE-LEFT, SIDEWAYS TO-THE-RIGHT, LITTLE-BIT BIGGER
'a red chair, not positioned to the left but sideways to the right, one that's a little bit bigger'

For the purpose of the current analyses, the first and third descriptions of the four objects that had to be described three times were annotated and analysed. The items that were described twice as well as the second descriptions of the items that were described three times were not analysed. The choice to focus on the first and third (hence initial and repeated) descriptions of the items that had to be described three times was made mainly because we expected the effects of repetition, if any, to be largest between the first and third descriptions. The four objects that were analysed were never described in the first or last trial within a set of 15 trials of one picture grid, and there were always at least two trials in between trials dealing with the same object. The focus on these initial and repeated descriptions means that the current analyses are based on a data set which consists of eight descriptions (one initial and one repeated description for two pictures from each domain grid) for each of the 14 participants (directors), leading to a total of 112 object descriptions.

2.3 Procedure

The director and the matcher faced one another across a table. A camera was positioned behind the matcher filming the upper body and hands of the director (see Figure 3 for an example).



Figure 3. Camera view of the director, camera is positioned behind the matcher.

The director had a laptop screen to his or her side and the matcher had a picture card in front of him or her. The director and matcher could see each other directly, but could not see each other's screen or card. The participants were given written instructions and had the opportunity to ask questions to the experimenter, after which the experiment started. The director was then presented with a trial on the computer screen (as in Figures 1 and 2). The director was asked to provide a description of the target object in such a way that the matcher could distinguish it from the 15 distractor objects. The matcher had a picture card filled with 16 numbered objects (see Figure 4 for an example) in front of him or her, which was not visible to the director. The matcher's card showed the same objects as on the director's screen, but these objects were ordered differently for the director and the matcher and only the matcher's objects were numbered. The difference in ordering meant that the director could not use the location of the target object on the grid



Figure 4. Picture card of one of the furniture grids as presented to the matcher.

as part of the description, and this was explicitly communicated to the participants. The difference in ordering also meant that the matcher could not use the director's eye gaze on the screen as a potential cue as to which item was being described. Based on the director's target description, the matcher had to write down the number of the object the director was describing. Once the correct object was found, the director went on to the next trial.

The matcher could make clear to the director whether the target object had been found or not, but there was no free conversation between the director and the matcher. This lack of conversation means that our analyses are based on complete, uninterrupted descriptions given by the director. After 15 trials from the people domain, the director was shown a second grid containing 16 objects from the other domain (the furniture domain), and the matcher was presented with a new card showing these objects (again in a different order from the order in which they were presented to the director and only numbered for the matcher, as in Figure 4). The participants did not have any problems in conducting the task (all matchers were successful in selecting the correct picture in all cases), did not produce any restarts or question-like realizations, and were not interrupted by the matcher. The entire task took the participants about 20 minutes. In two cases, there was only one participant present; therefore in these cases, the experimenter (who was fluent in NGT) fulfilled the role of the matcher (the experimenter obviously never acted as the director).

2.4 Data analysis

As mentioned above, analysis has taken place for the first (initial) and third (repeated) references to the objects that had to be described three times, leading to a total of 112 object descriptions. The aim was to look at how long the descriptions took and how many signs were used in these descriptions, as well as at how the signs themselves were produced. We used the multimodal annotation programme ELAN (Wittenburg, Brugman, Russel, Klassmann & Sloetjes 2006) to annotate the descriptions. We annotated the duration of the target descriptions by selecting the beginning and end point of each trial in ELAN, using a beep sound that was present at the beginning of each trial as the starting and cut-off point. We looked at the number of lexical signs that were produced and their duration by selecting the beginning and end point of each sign in ELAN. A sign was considered as such on the basis of Kendon's (1980) movement based convention of the gesture phrase, meaning that a sign can, but does not have to, contain up to five gesture phases (preparation, pre-stroke hold, stroke, post-stroke hold, and retraction) and always includes a stroke. We also analysed sign precision. In order to measure

sign precision, a separate perception test was used, which will be discussed below under Experiment II.

All data annotated in ELAN was exported into SPSS. The statistical procedure consisted of two repeated measures ANOVAs, one by participants (F_1) and one by items (F_2). On the basis of these results, the *minF'* (Clark 1973) was calculated, which indicates whether the results can be generalised over both participants and items. The experiment consisted of a $2 \times 2 \times 2$ design, with factors domain (levels: people, furniture), repetition (levels: initial, repeated), and picture (levels: one, two). We only report where results are significant.

To check whether the fact that in two cases the matcher was the experimenter might have had an effect on the participants' behaviour, we performed an additional analysis with the type of interlocutor (participant or the experimenter) as a between subjects variable. There were no significant main effects of the type of interlocutor on any of our dependent variables, and there were no interactions with type of interlocutor, which means that there were no noticeable differences in the data between participants who took part twice and those who took part only once (as director). Therefore, the type of interlocutor was excluded as a variable from our further analyses.

To check whether sign experience had an impact on our results, we divided the group of signers in two groups, one consisting of signers that had been signing NGT since before age 10, and one consisting of signers that only started to learn NGT after this age. We then performed another additional analysis with two between subjects variables added to the design, one indicating whether a participant had been born deaf or not, and one indicating whether the participants had been signing NGT since before age 10, or not. Also for these two variables there were no significant main effects on any of the dependent variables and there were also no significant interactions with either of these two variables. As with the type of interlocutor, we therefore also excluded these two variables from the final analyses.

2.5 Results

Firstly, Table 1 shows the average duration of the target descriptions, in seconds, of initial and repeated references. Speakers took significantly less time in describing repeated references ($M = 14.4$, $SD = 5.5$, 95% CI = (11.3, 17.6)) than initial references ($M = 24.2$, $SD = 8.4$, 95% CI = (19.4, 29.1)), $F_1(1, 13) = 35.14$, $p < .001$, $\eta_p^2 = .730$; $F_2(1, 4) = 22.30$, $p < .01$, $\eta_p^2 = .848$, *minF'* (1, 10) = 13.64, $p < .01$. Table 1 also shows the results for the average number of signs that were produced during initial and repeated references, and here the picture is similar. Speakers produced significantly fewer signs in repeated references ($M = 5.6$, $SD = 1.2$, 95% CI = (4.9, 6.3)) than in initial references ($M = 8.2$, $SD = 2.1$, 95% CI = (6.9, 9.4)), $F_1(1, 13) = 42.51$, $p < .001$,

$\eta_p^2 = .766$; $F_2(1, 4) = 16.59$, $p < .05$, $\eta_p^2 = .806$, $\min F'(1, 7) = 11.93$, $p < .05$.³ Finally, Table 1 illustrates the average sign duration, in seconds, of signs in initial and repeated references, and again the same general pattern can be observed. The average duration of signs was shorter in repeated references ($M = 1.2$, $SD = .20$, 95% CI = (1.1, 1.3)) than in initial references ($M = 1.5$, $SD = .28$, 95% CI = (1.3, 1.6)), $F_1(1, 13) = 15.1$, $p < .01$, $\eta_p^2 = .537$; $F_2(1, 4) = 20.17$, $p < .05$, $\eta_p^2 = .834$, $\min F'(1, 14) = 8.63$, $p < .05$. In sum: we find systematic effects of repetition, in that repeated references are shorter, contain fewer signs, and shorter signs than initial references. These effects were the same for both domains (furniture and people) and for all pictures; in particular, we found no significant interaction between the factors repetition and domain or repetition and picture, although references to people contained more signs in general than references to furniture items, in line with speech results from previous work (Koolen et al. 2011).

Table 1. Overview of mean results for dependent variables (duration of description in seconds, number of signs, and sign duration in seconds) for initial and repeated references, in the production experiment.

	Initial (SD)	Repeated (SD)
Duration	24.2 (8.4)	14.4 (5.5)
Number of signs	8.2 (2.1)	5.6 (1.2)
Sign duration	1.5 (.28)	1.2 (.20)

To illustrate, Figures 5 and 6 show a case of reduction in the description of a target object from the furniture domain. In the initial description, the participant takes longer and uses more signs and seemingly more precise signs than in the repeated description.

2.6 Conclusion experiment I: production experiment

The results from experiment I show that several aspects of NGT were reduced in repeated references. Repeated references produced by signers of NGT were shorter than initial references, and repeated references in NGT contained fewer and shorter signs than initial references. These results suggest that, at least for the aspects taken into account here, repeated references in NGT behaved as repeated references in speech described in previous studies. Repeated references by signers of NGT, containing predictable information, were produced in a more efficient way than initial references. Experiment I has also shown that it is possible to adapt

3. The assumption of sphericity is by definition always met in our design. However, the number of signs was not normally distributed, and for sake of conservativeness, necessary corrections have been applied.



SOFA, THREE SEATS, ASKEW, BIG, TO-THE-RIGHT, TO-THE-SIDE

Figure 5. Still and gloss of initial description of a sofa, lasting 48 seconds. The NGT sign depicted in the still is SOFA, with a fairly large extension and well-defined edges (as indicated by the arrows).



SOFA, GREEN, TURNED-AROUND, THREE SEATS

Figure 6. Still and gloss of repeated description of the same sofa, lasting 17 seconds. The NGT sign depicted in the still is SOFA, with smaller extension than in Figure 5 and without well-defined edges (as indicated by the arrows).

methods used to study reduction in speech (and gesture) in order to look at reduction in sign language.

3. Experiment II: perception test

As part of our analyses we wanted to also analyse sign precision. Since it is difficult to define objective measures with which to measure sign precision, a perception test was set up in which participants had to judge, in a forced choice task, which sign they considered to be the most precise, looking at pairs of video clips with signs produced in either initial or repeated references. This perception test was administered with two groups of participants: deaf NGT signing participants, and hearing Dutch participants with no knowledge of NGT. We will discuss each participant group separately.

3.1 Group 1: deaf NGT signers

3.1.1 *Participants*

Six NGT signing participants (one male, five female, age range 18–56 years old, $M=33$ years and 8 months), who were all deaf and had been signing NGT for over 10 years, took part without receiving any form of compensation.

3.1.2 *Stimuli*

The participants were presented with a PowerPoint presentation in which they saw 40 trials, consisting of 40 pairs of video clips. Each pair of video clips was presented on one slide (as shown in Figure 7).

Both video clips showed the same sign produced by the same signer of NGT about the same object, as described in the director-matcher task, except that in one video clip, the sign was produced in an initial reference and in the other video clip, the sign was produced in a repeated reference. The signs were selected on the basis of their availability in the data set from the director-matcher task, meaning that a sign had to be produced in both an initial and in a repeated description in order to be included in this data set. Signs that were only produced in an initial or only

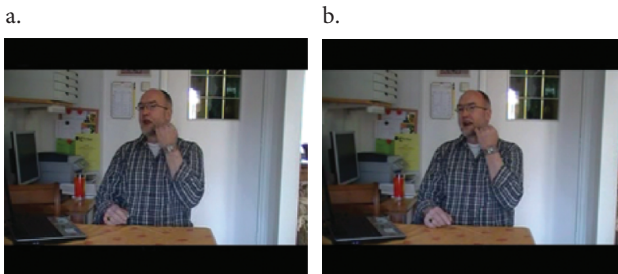


Figure 7. Example of presentation manner of one pair of video clips to a participant in the perception test.

in a repeated description were left out, and signs that were produced in a different context in the initial description compared to the repeated reference were also left out (for example, an initial sign which was produced at the beginning of the initial description where the repeated sign was produced at the end of the repeated description). Pairs of signs could be from either the people or the furniture domain and were clustered together in the perception test on the basis of their semantic meaning. This means that participants in the perception test were first presented with a number of video clip pairs showing tokens of one sign, e.g. DESK, followed by a cluster of video clip pairs showing tokens of another sign, e.g. WOMAN. The order in which the participants were presented with initial versus repeated signs in the video clip pairs was counterbalanced over pairs of video clips (that is, it was not the case that for each pair, the first video clip they saw was always the sign produced in an initial reference).

3.1.3 Procedure

The participants were given written instructions (in Dutch) and had the opportunity to ask questions to the experimenter, after which the experiment started. The participants had to watch the pairs of video clips, one video clip at a time, and were allowed to watch a video clip more than once if they wanted to. The task was to decide for each pair of video clips which sign they considered to be the most precise (the sign in video clip A or B). The task was a self-paced forced choice task, and even though the participants were allowed to watch the video clips more than once, they were encouraged to go with their first intuition. Participants were not allowed to go back to a previous stimulus item once they had made their decision. The only instruction they were given was to choose which sign they considered to be the “most precise”. No details were given to suggest what the participants should base this judgment on.

3.1.4 Data analysis

For each trial, one point was administered when a participant considered the sign from the initial reference to be the most precise and zero points were administered when the participant considered the sign from the repeated reference to be the most precise. These scores mean that if all participants considered all signs from initial references to be the most precise, the mean score should be 1, and if all participants considered all signs from repeated references to be more precise than the signs from the initial references, the mean score should be 0. If the mean score is higher than 0.5, then signs from initial references are considered to be more precise than signs from repeated references. Statistical analyses consisted of a one sample t-test (t_1) on the mean score, with 0.5 as test value, to test whether there was an effect of initial versus repeated video clips.

3.1.5 Results

The mean score for the NGT signing participants was 0.52 ($SD = .10$); this is not significantly higher than chance (0.5), $t(5) = .405$, $p = .70$ and shows that signs produced in initial references were not considered to be more precise than signs produced in repeated references.

3.1.6 Discussion

There was no effect of repetition on sign precision as judged by the NGT signing participants. However, the comments given by some of the participants during the experiment (such as “this one could be a bit bigger”) suggest that maybe the NGT signers interpreted *precision* as *intelligibility*, and reached ceiling effect because both initial and repeated signs were intelligible. Alternatively, the NGT signers did not interpret precision as intelligibility, but were simply not very good at phonetic discrimination, possibly because the difference between the initial and the repeated signs was not communicatively relevant. To check whether any of these suggestions might be true, we conducted the same experiment with nonsigners, i.e. participants with no knowledge of NGT, as will be described in the next section.

3.2 Group 2: hearing nonsigners

The strategy to conduct the same experiment with nonsigners was chosen, since research has shown that nonsigners can have a high degree of sensitivity to visual prosodic cues of a sign language (e.g. Brentari, Gonzalez, Seidl & Wilbur 2011). In Brentari et al.’s work, for example, nonsigners were highly accurate in identifying breaks and non-breaks between signs. The assumption here is that participants with no knowledge of NGT will not be influenced or distracted by the lexical meaning of the signs since the meaning of the signs is not communicatively relevant for them.

3.2.1 Participants

27 participants took part in the perception test. The participants were Dutch first year university students (9 male, 16 female, age range 18–30 years old, $M = 21$ years and 4 months), who had no knowledge of NGT and who took part as partial fulfilment of course credits. The stimuli, procedure, and data analysis were the same as for the NGT signing participants.

3.2.2 Results

The mean score for the nonsigners was 0.67 ($SD = .08$), which was significantly higher than 0.5, $t(26) = 11.013$, $p < .001$, and shows that signs from initial references were considered to be more precise than signs from repeated references.

Contrary to the NGT signing participants, the participants with no knowledge of NGT judged signs taken from initial references to be more precise than signs taken from repeated references.

When we analyse the data of all participants together, by conducting an independent samples t-test, we find that there is a significant difference between the NGT signing and non-NGT signing participants, $t(31) = 4.068$, $p < .001$.

3.3 Conclusion experiment II: perception test

The results from experiment II show that, for the nonsigners, signs produced in repeated reference were considered to be less precise than signs produced in initial references. However, we also found that the NGT signing participants did not consider the signs from repeated references as less precise than the signs from initial references, perhaps because they were distracted or influenced by the lexical meanings of the signs.

In general, the results of experiment II lend further support to the findings of experiment I, namely that it is possible to use methods from speech and gesture research to study reduction in sign language, and that there indeed appears to be reduction in repeated references in NGT.

4. General discussion and conclusion

Summarising the results from the production and perception experiments, we found evidence suggesting that there is reduction in repeated references in sign language. We showed that repeated references were shorter, contained fewer and shorter signs, and that signs produced in repeated references were considered to be less precise by nonsigners than signs in initial references.

The present results on sign language can be tied in with previous findings, both for speech and for gesture, that language users tend to be efficient by reducing predictable information. Relating the results to previous work on speech, we showed that repeated references were shorter and contained fewer signs than initial references, in line with work by Clark and Wilkes-Gibbs (1986) and Galati and Brennan (2010). The result that signs in repeated references were shorter can also be related to previous work on speech by Aylett and Turk (2004), Lam and Watson (2010), and Bell et al. (2009), where it was found that predictable speech (through redundancy or repetition) had a shorter duration than unpredictable speech. Our finding that signs in repeated references were considered to be less precise can be viewed as an extension of the work by Bard et al. (2000), who found that repeated references had a less clear pronunciation than initial references.

When we compare the results from the present study to those of previous work on co-speech gestures, we can also see certain connections. It has been found that gestures with common ground are less precise than gestures without common ground (Gerwing & Bavelas 2004). This can be related to our finding that signs in repeated references were considered to be less precise by the nonsigning participants. Work on the effect of repeated references on gestures (Hoetjes et al. 2011) found that repetition may cause a reduction in the number of gestures, as was found in the present study for the number of signs. Moreover, their finding that gestures in repeated references were considered to be less precise than gestures in initial references, can be directly mapped onto the present results for signs. Importantly, the reduction found in the current study can be tied in with work on language efficiency and cannot be explained through a general reduction over time (as discussed in e.g. Singleton, Morford & Goldin-Meadow 1993; Supalla 2008) with participants becoming more 'sloppy' in the course of the experiment. We only found a main effect of repetition even though initial and repeated pictures occurred throughout the experiment, and we found no effect of picture, even though the different pictures occurred in different positions in the experiment. In short, the present study is the first study on sign language that shows that signers (of NGT, in our case) behave similarly when describing repeated references to what previous studies have found for speech and gesture in speakers of spoken languages.

Due to the fact that there is only little previous work on reduction in sign language, the method used in the current study was inspired by relevant previous work on speech and gesture. We looked at fairly course-grained and modality-independent (i.e. applicable to speech, gesture, and sign) measures such as duration of the description and number of signs and not at more sign-specific aspects such as exact sign location (as has been done by e.g. Tyrone & Mauk (2010)). We looked at overall differences between initial and repeated descriptions and did not make pair-wise comparisons between signs from initial references and signs from repeated references. Despite this course-grained approach and the fact that our measures were not based on sign characteristics per se, we were still able to see that reduction in sign language occurs. Our results show that it is possible to use such modality-independent methods to study reduction in repeated references. Studying reduction in sign language is an interesting addition to previous work on speech and gesture. Considering that signs can be argued to be both like speech (they are lexical) and like gesture (they are produced with the hands), it is interesting to see that in the present study, signs behaved in a way similar to what previous studies found for speech, on the one hand, and for gesture, on the other hand.

Naturally, the current study has certain limitations and leaves room for further research. Presently, we only looked at fairly coarse-grained measures such as

the duration of the target descriptions, the number of signs, the duration of these signs, and the perceived precision of the signs. Although these course-grained measures were useful for a first study on repeated references in sign language, it can be argued that many more aspects of the signed references need to be studied. The present analyses have already shown that signers of NGT reduce their descriptions in repeated references, but the finer details of the reduction that may be present in the description have not yet been taken into account. As for ‘finer details’, one could think of characteristics of the signs themselves such as the exact hand-shape of the sign, or the sign location, as has been studied previously by Tyrone and Mauk (2010), but one could also think of details about the entire reference. Aspects of the entire reference that could be studied are, for example, which lexical signs are used for which reference, showing how much vocabulary overlap there is between the initial and the repeated references. One could also look at whether sign duration does not only depend on whether a sign is produced in an initial or in a repeated reference but also include in the analysis whether the exact position of a particular sign within the reference has an effect. The current analyses were based on the overall references, and, at least for the production experiment, we did not compare lexically identical sets of initial and repeated signs, something which could be done in future research. Considering that the present study is a first look at reduction in repeated references in a sign language, we also do not know to what extent the results from the current study can be generalised to other repeated references and other forms of predictable information in general, or whether the results might be specific to this type of task.

When we focus on the perception experiment (Experiment II), several aspects deserve discussion. Firstly, the results showed an effect of repetition on sign precision, but only for the nonsigners. The NGT signing participants did not consider signs from initial references to be more precise than signs from repeated references. It might be the case that the reductions in sign precision were either not picked up, or were mentally compensated by the NGT signing participants, because these reductions might not be linguistically or communicatively relevant for the NGT signers. Because of this, we decided to also run the experiment with nonsigners, whose precision judgments could not be affected by lexical interpretations. In addition, there are reasons to assume that the use of nonsigners is indeed a reasonable approach. As mentioned above, previous research (e.g. Brentari et al. 2011) has shown that nonsigners are very capable in recognizing visual prosodic cues of a sign language.

A second point of discussion is that the participants of the perception test were not told what to base their precision judgment on. This was done on purpose since the term “precision” can mean different things to different people, which is exactly why it is difficult to measure objectively. However, to avoid the possibility

that different participants might have interpreted the task differently, it would be possible in future work, especially when using NGT signing participants, to set up the task slightly differently, for example by asking participants to recognise a sign's meaning, as in Bard et al.'s (2000) work on speech, instead of judging a sign's precision. Another option would be to explain the entire setup of the experiment to the participants and ask them to judge which sign was produced in an initial reference and which one in a repeated reference.

In sum, the analyses done in the present study showed us not only that we can use analyses from related work on speech and gesture and adapt them to analyse signs in repeated references, but also that signers of NGT do reduce their repeated references. In fact, the ways in which these repeated references are reduced in NGT are quite similar to what has been found previously for speech and gesture. It is well known that speakers of oral languages are communicatively efficient by reducing predictable information, both in speech and in co-speech gestures. This study has shown, for the first time, that signers design their utterances to be efficient in similar ways.

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References

- Altmann, Gabriel. 1980. Prolegomena to Menzerath's law. *Glottometrika* 2. 1-10.
- Arnold, Jennifer E. 2008. Reference production: production-internal and addressee-oriented processes. *Language and Cognitive Processes* 23(4). 495-527. DOI: 10.1080/01690960801920099
- Arnold, Jennifer E., Jason M. Kahn & Giulia C. Pancani. 2012. Audience design affects acoustic reduction via production facilitation. *Psychonomic Bulletin and Review* 19(3). 505-512. DOI: 10.3758/s13423-012-0233-y
- Aylett, Matthew & Alice Turk. 2004. The smooth signal redundancy hypothesis: a functional explanation for relationships between redundancy, prosodic prominence, and duration in spontaneous speech. *Language and Speech* 47(1). 31-56. DOI: 10.1177/00238309040470010201

- Bard, Ellen G., Anne H. Anderson, Catherine Sotillo, Matthew Aylett, Gwyneth Doherty-Sneddon & Alison Newlands. 2000. Controlling the intelligibility of referring expressions in dialogue. *Journal of Memory and Language* 42. 1-22. DOI: 10.1006/jmla.1999.2667
- Bard, Ellen G. & Matthew Aylett. 2005. Referential form, duration, and modelling the listener in spoken dialogue. In John Trueswell & Michael Tanenhaus (eds.), *Approaches to studying world-situated language use: Bridging the language-as-product and language-as-action traditions*, 173-191. Cambridge, MA: MIT Press.
- Bell, Alan, Jason Brenier, Michelle Gregory, Cynthia Girand & Dan Jurafsky. 2009. Predictability effects on durations of content and function words in conversational English. *Journal of Memory and Language* 60. 92-111. DOI: 10.1016/j.jml.2008.06.003
- Brennan, Susan & Herb Clark. 1996. Conceptual pacts and lexical choice in conversation. *Journal of Experimental Psychology* 22(6). 1482-1493.
- Brentari, Diane. 1998. *A prosodic model of sign language phonology*. Cambridge, MA: MIT Press.
- Brentari, Diane. 2002. Modality differences in sign language phonology and morphophonemics. In Richard P. Meier, Kearsy A. Cormier & David G. Quinto-Pozos (eds.), *Modality and structure in signed and spoken languages*, 35-64. Cambridge: Cambridge University Press.
- Brentari, Diane, Carolina Gonzalez, Amanda Seidl & Ronnie B. Wilbur. 2011. Sensitivity to visual prosodic cues in signers and nonsigners. *Language and Speech* 54(1). 49-72. DOI: 10.1177/0023830910388011
- Clark, Herb. 1973. The language-as-fixed-effect fallacy: a critique of language statistics in psychological research. *Journal of Verbal Learning and Verbal Behavior* 12. 335-359. DOI: 10.1016/S0022-5371(73)80014-3
- Clark, Herb & Diane Wilkes-Gibbs. 1986. Referring as a collaborative process. *Cognition* 22. 1-39. DOI: 10.1016/0010-0277(86)90010-7
- Crasborn, Onno. 2001. *Phonetic implementation of phonological categories in sign language of the Netherlands*. PhD dissertation, LOT, Utrecht.
- de Ruiter, Jan P., Adrian Bangerter & Paula Dings. 2012. The interplay between gesture and speech in the production of referring expressions: investigating the trade-off hypothesis. *Topics in Cognitive Science* 4(2). 232-248. DOI: 10.1111/j.1756-8765.2012.01183.x
- Ernestus, Mirjam & Natasha Warner. 2011. An introduction to reduced pronunciation variants [Editorial]. *Journal of Phonetics* 39. 253-260. DOI: 10.1016/S0095-4470(11)00055-6
- Fenk, August & Gertraud Fenk-Oczlon. 1993. Menzerath's law and the constant flow of linguistic information. In Reinhard Köhler & Burghard Rieger (eds.), *Contributions to quantitative linguistics*, 11-31. Dordrecht: Kluwer Academic Publishers. DOI: 10.1007/978-94-011-1769-2_2
- Fenk-Oczlon, Gertraud. 2001. Familiarity, information flow, and linguistic form. In Joan Bybee & Paul Hopper (eds.), *Frequency and the emergence of linguistic structure*, 431-448. Amsterdam: John Benjamins.
- Ferreira, Victor S. 2008. Ambiguity, accessibility, and a division of labor for communicative success. *Learning and Motivation* 49. 209-246. DOI: 10.1016/S0079-7421(08)00006-6
- Fowler, Carol A. 1988. Differential shortening of repeated content words produced in various communicative contexts. *Language and Speech* 31(4). 307-319.
- Fowler, Carol A. & Jonathan Housum. 1987. Talkers' signaling of 'new' and 'old' words in speech and listeners' perception and use of the distinction. *Journal of Memory and Language* 26(5). 489-504. DOI: 10.1016/0749-596X(87)90136-7

- Galati, Alexia & Susan Brennan. 2010. Attenuating information in spoken communication: for the speaker, or for the addressee? *Journal of Memory and Language* 62. 35-51. DOI: 10.1016/j.jml.2009.09.002
- Gee, James & Wendy Goodhart. 1988. American Sign Language and the human biological capacity for language. In Michael Strong (ed.), *Language learning and deafness*, 49-74. Cambridge: Cambridge University Press. DOI: 10.1017/CBO9781139524483.004
- Gerwing, Jennifer & Janet Bavelas. 2004. Linguistic influences on gesture's form. *Gesture* 4. 157-195. DOI: 10.1075/gest.4.2.04ger
- Grice, Herbert P. 1975. Logic and conversation. In Peter Cole & Jerry L. Morgan (eds.), *Syntax and semantics 3: Speech acts*, 41-58. New York: Academic Press.
- Gundel, Jeanette K., Nancy Hedberg & Ron Zacharski. 1993. Cognitive status and the form of referring expressions in discourse. *Language* 69. 274-307. DOI: 10.2307/416535
- Hoetjes, Marieke, Ruud Koolen, Martijn Goudbeek, Emiel Krahmer & Marc Swerts. 2011. GREEBLES Greeble greeb. On reduction in speech and gesture in repeated references. In Laura Carlson, Christoph Hoelscher & Thomas F. Shipley (eds.), *33rd annual conference of the Cognitive Science Society*, 3250-3255. Boston: Cognitive Science Society.
- Holler, Judith & Katie Wilkin. 2009. Communicating common ground: how mutually shared knowledge influences speech and gesture in a narrative task. *Language and Cognitive Processes* 24(2). 267-289. DOI: 10.1080/01690960802095545
- Jaeger, Tim Florian. 2010. Redundancy and reduction: speakers manage syntactic information density. *Cognitive Psychology* 61(1). 23-62. DOI: 10.1016/j.cogpsych.2010.02.002
- Jaeger, Tim Florian & Harry Tily. 2011. Language processing complexity and communicative efficiency. *WIREs: Cognitive Science* 2(3). 323-335. DOI: 10.1002/wcs.126
- Johnson, Robert E. & Scott K. Liddell. 2010. Toward a phonetic representation of signs: sequentiality and contrast. *Sign Language Studies* 11(2). 241-274. DOI: 10.1353/sls.2010.0008
- Kelly, Spencer D., Sarah M. Manning & Sabrian Rodak. 2008. Gesture gives a hand to language and learning: perspectives from cognitive neuroscience, developmental psychology and education. *Language and Linguistics Compass* 2(4). 569-588. DOI: 10.1111/j.1749-818X.2008.00067.x
- Kendon, Adam. 1980. Gesture and speech: two aspects of the process of utterance. In Mary R. Key (ed.), *Nonverbal communication and language*, 207-227. The Hague: Mouton.
- Kendon, Adam. 2004. *Gesture. Visible action as utterance*. Cambridge: Cambridge University Press.
- Klima, Edward S. & Ursula Bellugi. 1979. *The signs of language*. Cambridge, MA: Harvard University Press.
- Koolen, Ruud, Albert Gatt, Martijn Goudbeek & Emiel Krahmer. 2011. Factors causing over-specification in definite descriptions. *Journal of Pragmatics* 43(13). 3231-3250. DOI: 10.1016/j.pragma.2011.06.008
- Krahmer, Emiel & Marc Swerts. 2007. The effects of visual beats on prosodic prominence: acoustic analyses, auditory perception and visual perception. *Journal of Memory and Language* 57. 396-414. DOI: 10.1016/j.jml.2007.06.005
- Lam, Tuan Q. & Duane G. Watson. 2010. Repetition is easy: why repeated referents have reduced prominence. *Memory and Cognition* 38(8). 1137-1146. DOI: 10.3758/MC.38.8.1137
- Leuninger, Helen, Annette Hohenberger, Eva Waleschkowski, Elke Menges & Daniela Happ. 2004. The impact of modality on language production: Evidence from slips of the tongue and hand. In Thomas Pechmann & Christopher Habel (eds.), *Multidisciplinary approaches to language production*, 219-277. Berlin: Mouton de Gruyter.

- Liddell, Scott K. & Robert E. Johnson. 1989. American Sign Language: the phonological base. *Sign Language Studies* 64. 195-277. DOI: 10.1353/sls.1989.0027
- Lieberman, Philip. 1963. Some effects of semantic and grammatical context on the production and perception of speech. *Language and Speech* 6(3). 172-187.
- Lindblom, Björn. 1990. Explaining variation: a sketch of the H and H theory. In William Hardcastle & Alain Marchal (eds.), *Speech production and speech modelling*, 403-439. Dordrecht: Kluwer Academic Publishers. DOI: 10.1007/978-94-009-2037-8_16
- Mauk, Claude E., Björn Lindblom & Richard P. Meier. 2008. Undershoot of ASL locations in fast signing. In Josep Quer (ed.), *Signs of the time. Selected papers from TISLR 8*, 3-24. Hamburg: Signum.
- McNeill, David. 1992. *Hand and mind. What gestures reveal about thought*. Chicago: University of Chicago Press.
- Russell, Kevin, Erin Wilkinson & Terry Janzen. 2011. ASL sign lowering as undershoot: a corpus study. *Laboratory Phonology* 2(2). 403-422. DOI: 10.1515/labphon.2011.015
- Samuel, Arthur G. & Mateusz Troicki. 1998. Articulation quality is inversely related to redundancy when children or adults have verbal control. *Journal of Memory and Language* 39(2). 175-194. DOI: 10.1006/jmla.1998.2580
- Sandler, Wendy. 1989. *Phonological representation of the sign: Linearity and nonlinearity in American Sign Language*. Dordrecht: Foris. DOI: 10.1515/9783110250473
- Sandler, Wendy & Diane Lillo-Martin. 2006. *Sign language and linguistic universals*. Cambridge: Cambridge University Press. DOI: 10.1017/CBO9781139163910
- Schembri, Adam, David McKee, Rachel McKee, Sara Pivac, Trevor Johnston & Della Goswell. 2009. Phonological variation and change in Australian and New Zealand Sign Languages: The location variable. *Language Variation and Change* 21. 193-231. DOI: 10.1017/S0954394509990081
- Shannon, Claude. 1948. A mathematical theory of communications. *Bell Systems Technical Journal* 27(4). 623-656. DOI: 10.1002/j.1538-7305.1948.tb00917.x
- Singleton, Jenny L., Jill P. Morford & Susan Goldin-Meadow. 1993. Once is not enough: standards of well-formedness in manual communication created over three different timespans. *Language* 69. 683-715. DOI: 10.2307/416883
- Stokoe, William C. 2005. Sign language structure: an outline of the visual communication systems of the American Deaf. *Journal of Deaf Studies and Deaf Education* 10(1). 3-37. DOI: 10.1093/deafed/eni001
- Supalla, Ted. 2008. Sign language archeology: integrating historical linguistics with fieldwork on young sign languages. In: Ronice Müller de Quadros (ed.), *Sign languages: spinning and unraveling the past, present, and future. Forty-five papers and three posters from the 9th theoretical issues in sign language research conference*, Florianópolis, Brazil, December 2006. Petrópolis: Editora Arara Azul. [Available at: www.editora-arara-azul.com.br/EstudosSurdos.php].
- Tyrone, Martha E. & Claude E. Mauk. 2010. Sign lowering and phonetic reduction in American Sign Language. *Journal of Phonetics* 38. 317-328. DOI: 10.1016/j.wocn.2010.02.003
- Van Deemter, Kees, Albert Gatt, Ielka van der Sluis & Richard Power. 2012. Generation of referring expressions: Assessing the incremental algorithm. *Cognitive Science* 36(5). 799-836. DOI: 10.1111/j.1551-6709.2011.01205.x
- van der Hulst, Harry. 1993. Units in the analysis of signs. *Phonology* 10(2). 209-241. DOI: 10.1017/S095267570000004X

- van der Sluis, Ielka & Emiel Krahmer. 2007. Generating multimodal referring expressions. *Discourse Processes* 44(3). 145-174. DOI: 10.1080/01638530701600755
- Wittenburg, Peter, Hennie Brugman, Albert Russel, Alex Klassmann & Han Sloetjes. 2006. ELAN: a professional framework for multimodality research. Paper presented at the *5th International Conference on Language Resources and Evaluation (LREC 2006)*. Genoa, Italy, 24–26 May 2006.
- Zipf, George K. 1936. *The psychobiology of language*. London: Routledge.

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